ON LINE PROTECTION OF TRANSMISSION LINES USING MICROPROCESSOR

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JULY, 1983

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A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

By
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to the

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

JULY, 1983

Dedicated to

my mother

CERTIFICATE

Certified that this work 'ON LINE PROTECTION OF TRANSMISSION LINE USING MICROPROCESSOR' by V.P. Sunnak has been carried out under my supervision and has not been submitted elsewhere for a degree.

July 4,1983

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ACKNOWLEDGEMENTS

I am greatly indebted to Dr. L.P. Singh for suggesting the problem and providing his valuable guidance and encouragement throughout this work.

I am very much grateful to Shri A.G. Kothari, Shri K.V. Desikachar, H.K. Patel and Shri A.J. Kellogg for timely and fruitful discussions.

With gratitude, I wish to place on record the kind permission of Dr. R. Raghuram and Shri Joseph John for using laboratory facilities and for assistance in connection with the practical work.

I am thankful to my friends S/Shri A.R. Shalu, M.V. Govind, Capt. N.K. Pandey, J. Senthil and D.P. Sharma for thei kind assistance in completing my work and also to other friends who helped in one or the other way during the progress of the work.

This volume would not have been in its present form, if it were not the pains taking efforts of M/s J.S. Rawat, Ganga Ram and also, the Sri Bupinder Singh of Mechanical Engineering Department.

V.P. SUNNAK

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ABSTRACT

With the increase in complexity of power system network; the need for fast, efficient and reliable protection system has become a necessity. Protection schemes using electromechanical relays has numerous disadvantages and hence they were replaced in the beginning by electronic relays, then by solid state relays. Although these solid state relays are successful in operation, they have certain distinct disadvantages such as time of operation of relay is approximately 3-4 cycles, lack of flexibility and absence of self checking etc. These disadvantages have resulted in a trend towards the use of programmable equipment in place of hardwired systems.

The high speed clearance of fault on the complex power system network, very effectively improves the transient stability limit. The rotational kinctic energy introduced into a power system during a fault is proportional to the square of the fault clearance time. Therefore high speed clearance of faults close to large sources of generation will reduce the system acceleration move than any other form of dynamic control. The fault clearance time depend on the speed of protective relay as well as that of the associated

circuit breaker, the realisation of high speed protective relaying scheme has become imperative.

In this thesis, a review of various method using digital protection algorithms and design and development of microprocessor based on line protective relaying schemes for EHV/UHV transmission lines are outlined.

LIST OF FIGURES

LIST OF PRINCIPAL SYMBOLS

V_{pk}	:	Peak voltage
I_{pk}	:	Peak current
ω_1	:	normal power frequency of 50 hertz
ω_2	:	angular frequency corresponding to data window
V_d	:	direct axis component of voltage
V_g	:	quadrature axis component of voltage
I_d	:	direct axis component of current
I_q	:	quadrature axis component of current
A/D	:	Analogue to digital converter
S/H	:	Sample and Hold circuit
CPU	:	Central Processing unit
ROM	:	Read only memory
RAM	:	Random access memory
EPROM	:	Evaseable programmable read only memory

CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

For the protection of EHV/UHV transmission line, a fast, sensitive, reliable, efficient and low cost protection scheme is necessary. The sensitivity and selectivity of a protective scheme depends upon the type of the relay unit employed. Of the several electromagnetic measuring units available, the induction cup unit proved to be the best in distance relaying applications because of its faster speed (3-5 cycles) and greater sensitivity compared to the other types of electromechanical relays and also its ability to produce any type of conventional threshold characteristics.

However, with the advent of solid state devices, such as semiconductor diodes and transistors, a trend towards employing them for relaying purposes, has emerged. The need for faster measuring unit gave impetus to the development of solid state (i.e. static) relays in the initial stages.

The merits of static relays are greater sensitivity, higher speed, lower (VA) burden, no contact problems and immunity from vibrations and shocks etc. due to external causes. The static relays are being used increasingly in recent years, specifically for the protection of EHV/UHV

transmission lines where increased sensitivity, reliability and speed are of importance.

The selectivity, provided by a protective relaying scheme, depend to a great extent upon the type of threshold characteristics obtained from the relay unit employed in it. The selectivity, between the internal and external fault, can be achieved by the use of multizone directional distance relaying scheme with or without carrier current pilot schemes. The selectivity, between internal faults and other abnormal conditions, such as power swing etc. depend upon the shape of the threshold characteristics. The quadrilateral characteristics has proved to be the best in fulfilling these requirements to the maximum extent. The high speed clearance of faults on the complex power system network very effectively improves the transient state stability limit i.e. the power transfer capability for a given stability limit. The rotational kinetic energy introduced into a power system during a fault is proportional to the square of the fault clearance time. Therefore, high speed clearance of faults close to large sources of generation will reduce the system acceleration more than any other form of dynamic control which can be used only after the system is being accelerated. In the recent years, this aspect of improving transient stability has been drawing the

attention of quite a few research engineers and organisations. The fault clearance time depends on the speed of the protective relays as well as on that of the associated circuit breakers [1], the realization of high speed protective relaying scheme has become imperative because high speed circuit breakers are available.

Digital protection schemes are well ahead in this direction since programmable equipments are of self checking nature and fast responding type. Using programmable equipment, it is possible to realize move complex characteristics with less complexity in logic. The use of digital computer for the protection of power system equipment is of recent origin, the first proposal appearing in late 1960's. Also, very recently there has been a trend towards employing micro-processor and multiprocessor for the power system protection purposes. Microprocessors provide programmable logic at low costs. This has led protection engineers to use micro-computer in protection and other related areas which traditionally are the domains of analog devices. All these factors gave rise to the motivation for developing a microprocessor based distance relaying scheme for the protection of EHV/UHV transmission lines.

1.2 OBJECTIVE AND SCOPE

The objective and scope of the work reported in this thesis have been:

a) To present a critical review of the important solid state relaying schemes reported so far for the protection of long and heavily loaded EHV/UHV transmission lines,

b) To present an overview of the digital computer relaying algorithm developed uptill now as well as the philosophy behind the existing and proposed algorithms, and

c) To present the design and development of the proposed microprocessor based protection schemes for the EHV/UHV transmission lines.

1.3 LITERATURE SURVEY

In the past, over current relays were being used for the protection of transmission lines. However, increasing demand in the use of electrical energy throughout the world has necessitated a corresponding increase in the transmission line voltage to enable to transfer move power economically and efficiently and also complexity of the power system networks, these overcurrent relays were found to be unsuitable because of several demerits such as, shifting

of balance point with the change of generation capacity, type of faults and also switching transients. Also, these over current relays can be used only on systems where the minimum fault current exceed, the maximum load current. However, the directional over current relays are still being used as back up relay for ground fault relaying. On account of the above mentioned drawbacks associated with the over current relays, the distance relays have been developed. A brief and critical review of the important literature pertaining to the evolution of distance relays, travelling wave relays, digital relays, using digital computer and microprocessor for the protection of transmission lines, is presented in the following sections.

1.3.1 Distance Relays:

Distance relays are used primarily for the protection of transmission lines and, as their name implies, they measure distance, i.e. they recognize faults occuring within the protected section of the line from the fact that the distance from the relay to the fault is less than the setting of the relay.

1.3.1.1 Electromechanical Relay:

In the evolution of relays for the protection of transmission lines, the electromechanical relays were

developed first and in that of distance relays the plain impedance relay was first one that was conceived and developed. In 1923, Crichton [2] reported about an impedance relay which employed an induction disc actuating structure and operated in a time proportional to the impedance between the relay and the fault point. In 1928, Mclaughlin and Erickson [3] reported about a directional impedance time relay built with an induction disc actuating structure. They presented the constructional details and described the principle of operation alongwith the technique for obtaining proper voltage for the restraining element. In 1944, Goldsborough [4] reported about a modified impedance relay built with a balanced beam structure and described how a circular pick up characteristic of any desired radii and with any desired location of the centre could be obtained. In 1928 the induction disc type reactance relay was designed by Warrington [5] and performance of normal and high speed reactance relay was published by George [6]. In 1933, Warrington [7] reported about a high speed reactance relay which was built with a four-pole induction cup actuating structure carrying current coils on one pair of opposite poles, and current and voltage coils on each of other poles.

Though the mho relay was first used in 1933 as the directional unit for an early type reactance relay [7], its

independent use for the protection of heavily loaded long transmission lines was first recommended in 1943 by Warrington [8] with its merits lucidly brought out. In 1944, Cordrey and Warrington [9] described its actual use in a carrier current scheme. Later, Hutchinson [10] described its use in a three step distance relaying scheme in which protection for zone 1 and 2 was provided by normal mho units and for zone 3 by an offset mho unit. In 1962, Skuderna [11] put forth the mathematical development of how offset conic and limacon characteristics could be obtained with a four pole induction cup structure.

1.3.1.2 Electronic Relay

In 1934, Wilderoe [12] presented electronic circuits, incorporating thyratron tubes, which were equivalent of many electromechanical relays in use at that time. In 1948, MacPherson and Warrington [13] described an electronic mho relay wherein instantaneous values of voltage and current inputs to the relay were compared at the instant of voltage input maximum. In 1949, Loving published electronic circuits for many protective functions, and presented experimental results. In 1954, Bergseth published a paper [14] describing an electronic directional distance relay which was insensitive to modern waveform distortion. However with the advent of solid state devices, the development of these electronic relays ceased.

1.3.1.3 Solid State Relays:

The first serious proposal, for employment of transistorised circuits for power system protective relaying, came from Adanson and Wedepohl [15] in 1956. In this, they presented a mathematical theory for determining the inputs necessary to obtain the directional, ohm, offset impedance and mho characteristics with a two input phase comparator. Several papers have appeared on solid state relaying using the approach of dual input comparator and multi-input cos and sine phase comparators. In 1970, Ramamoorty and Wani [16] reported about the fabrication and test results of a solid state quadrilateral distance relay.

In 1980, Parthasarthy et.al. [17] presented a new distance relay with an adaptive pick up characteristics which has narrow tripping area during power swing conditions and which automatically expands to large area during unbalanced faults. A solid state distance relay, employing, an operational amplifier chip as an amplitude comparator and producing elliptical characteristic, was developed by Ramamoorty et.al. [18].

1.3.2 Digital Relaying:

The use of digital computer, and microprocessors for protective relaying purposes has been engaging the attention of research and protection engineers since late 1960.

The first serious proposal for using digital computer came from Rockefeller [19]. The algorithms proposed so far, involves in the determination of fundamental frequency impedance to the fault point from the fundamental components of voltage and currents whichn are extracted from the complex post fault waveform by analogue and/or digital filters. Mann and Morrison [20] described the predictive calculation of peak values of and the phase angle between the voltage and current from much fewer number of samples. Several algorithms were developed subsequently and tried by Ranjabar et al. and others [26].

The possibility of utilising an on line microprocessor (micro-computer) to perform the protection, switching and data collections of EHV/UHV transmission system is attracting increased attention. Of these functions, on line protection is likely to be the most exacting in terms of microprocessor based hard wired facilities.

A directional over current relay using microprocessor was developed by A.K. Ghai [21]. The relay hardware, apart from a microcomputer, consists of simple digital circuits, current measurement is carried out with expensive analague to digital converter. G. Thirupathaiah etc. [22] described the technique of developing a relay having quadrilateral characteristics based on fundamental frequency signal.

Y. Akimoto et.al. [23] developed a digital current differential carrier relaying using microprocessor. In 1977, Yoshiteru Miki [24] realised Mho and reactance relay characteristics and thus gave a new dimension to protection engineers in the digital relaying field.

The results, so far reported on various protection schemes for EHV/UHV transmission lines based on microprocessor application, have been obtained by simulating it on either digital computer or INTEL 8080 based microcomputer.

1.4 SUMMARY OF THE WORK REPORTED IN THIS THESIS

The summary of the work carried out and reported in this thesis, is presented below chapterwise.

Chapter 2 starts with an overview of digital algorithms for protective relaying schemes of EHV/UHV transmission lines alongwith major philosophies used in designing digital relaying schemes.

Chapter 3 deals with the theory and mathematical formulation including the algorithm for the digital simulation of the proposed relaying schemes. Also, the software realization of the proposed relaying schemes are given in this chapter.

Chapter 4 deals with the design, development and testing of microprocessor based relaying schemes. Different types of digital protection systems based upon their hardware implementation have also been discussed.

Finally, the thesis concludes with Chapter 5, which highlights briefly the work reported in this thesis along with the discussion of the result and scope of further work in this field.

CHAPTER 2

DIGITAL PROTECTION OF TRANSMISSION LINE

2.1 SUMMARY

This chapter gives an overview of digital algorithms and systems for protective relaying schemes of EHV/UHV transmission lines. Major philosophies used in designing digital relaying schemes are outlined.

2.2 PRINCIPLE OF DIGITAL PROTECTION

The principle of digital protection as applied to transmission line is described by a block diagram of simplified hardware configuration as shown in Fig. 2.1. An analog input subsystem accepts 3-phase ac quantities from power system through conventional CT's and PT's. All of these quantities are sampled simultaneously at predetermined sampling rate, converted to digital form using Analog to digital converters and then transferred to the digital processor. The processor stores, organises and makes decisions based on the value of samples with reference to the programme stored in the memory of processor. The main purpose of the processor is to send the tripping command to circuit breaker for isolation of line on occurance of internal faults.

2.3 ADVANTAGES OF DIGITAL PROTECTION

The main advantages of digital protection are given below.

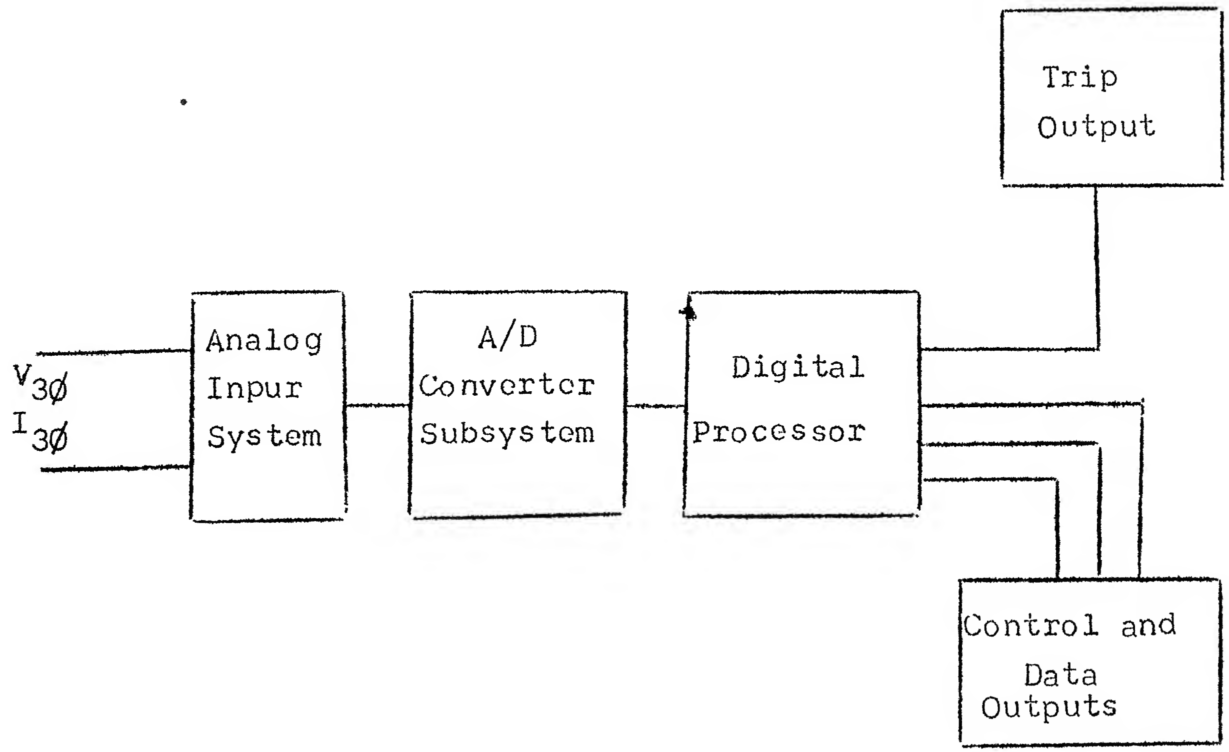


Fig. 2.1: Simplified Hardware Configuration

a) Possibility to realize sophisticated threshold characteristics of relays.

b) Easy to change the setting for alteration in system conditions.

c) Ability to check correctness of input and data missing or incorrect informations.

d) Interfacing with other controlling devices is possible.

e) It requires less maintenance

and f) It can give fault reports without specially designed devices, for post fault analysis.

2.4 DIGITAL TRANSMISSION LINE PROTECTION ALGORITHMS

Distance relays evaluate the line impedance by looking into the transmission line. The basic approaches being used in digital transmission line protection are of three types. These approaches depend on the form of the final input signal used to make the relaying decision. They are:

a) Transmission line protection based on system parameters.

b) Transmission line protection based on fundamental frequency signal.

c) Transmission line protection based on the signal containing both fundamental and transient frequencies.

2.4.1 Transmission Line Protection Based on System Parameters:

This assumes representation of a line by a set of differential equations. The most common model of a

transmission line is the one containing R and L as system parameters. The differential equation of this model is of the form,

$$v = Ri + L. \frac{di}{dt} \qquad (2.1)$$

This representation of a transmission line recognises the DC offset as a valid part of the polution and, therefore, no special features have to be implemented to suppress the DC offset. Calculated value of R and L using equation (2.1) are used for phase-distance and ground-distance relaying schemes. The set of equations is manipulated depending upon the type of fault, and the final equation obtained is of the form of equation (2.1), but actually contains some combination of current and voltage phase value to form v and i given in equation (2.1).

A number of algorithm have been suggested [43] to solve equation (2.1) numerically. In 1971, McInnes et al. [25] proposed an algorithm for this purpose. It proposed integration of equation (2.1) over two successive time periods so that a sufficient number of equation are obtained to solve for R and L. Integrals are evaluated numerically using trapezoidal rule and the final expression for R and L are of the form,

$$R = \frac{(v_{k-1}+v_k)(i_{k-1}-i_{k-2})-(v_{k-1}+v_{k-2})(i_k-i_{k-1})}{(i_{k-1}+i_k)(i_{k-1}-i_{k-2})-(i_{k-1}+i_{k-2})(i_k-i_{k-1})} \quad (2.2)$$

$$L = \frac{(v_{k-1}+v_{k-2})(i_{k-1}+i_k)-(v_{k-1}+v_k)(i_{k-1}+i_{k-2})}{(i_{k-1}+i_k)(i_{k-1}-i_{k-2})-(i_{k-1}+i_{k-2})(i_k-i_{k-1})} \times \frac{h}{2} \quad (2.3)$$

where v and i are instantaneous value of voltage and current, k is the instant and h is the time interval.

However, it should be noted that, there are several problems, associated with the characteristics of actual transmission line which are not accounted in equation (2.1). This equation assumes perfectly transposed transmission line, and neither the shunt capacitance nor the capacitance used for series compensation is considered in this case. The fault resistance and effect of power flow on the line at the instant of fault are also not considered.

A number of techniques can be developed to cope with some of the problems mentioned above. Of course, a quite powerful technique is to filter the input signal with a low pass filter, which enables the attenuation of the high frequency transients which are introduced by some of the effects mentioned above.

In 1975, Ranjbar et al. [26] developed another technique which relates appropriate integration interval of equation

(2.1) to the particular harmonics that are selected for removal. The sampling rate is related as a multiple of the order of the harmonic to be removed, which makes the procedure quite restrictive by the sampling rate selection and accuracy.

If a transmission line is represented by a single PI section, then an algorithm can be developed which will accommodate both the DC offset as well as high frequency transient componentsof the input signals without any additional filtering. In this case, the computational burden is increased, but when this algorithm is compared to an algorithm with the low-pass filtering procedure, then the overall computational burden of the two algorithms are not very different.

2.4.2 Transmission Line Protection Based on Fundamental Frequency Signal:

This relies on the theory of orthogonal transform [27]. The most widely used is the Fourier transform theory which utilizes the set of sine and cosine functions as an orthogonal set. Any function, then, can be represented as a sum of the combinations of the functions from the defined orthogonal set. Basic properties of the Fourier transform can be used to extract any particular frequency component from the incoming signal. The expression derived can be based on either

continuous or on the discrete Fourier transform. In the case of the continuous functions, some form of numerical approximation is done to obtain a digital solution. Ramamoorty [28] correlated samples of the input signals (voltage and current) with the stored samples of reference fundamental sine and cosine waves.

If the expressions of the waveforms are given in rectangular form, then the general expressions for the sine and cosine component of voltage for sample point k are given as [29],

$$V_s = \frac{1}{N} [2 \sum_{\ell=1}^{N-1} V_{k-N-1} \sin (\frac{2\pi}{N} \ell)] \tag{2.4}$$

$$V_c = \frac{1}{N} [V_{K-N} + V_K + 2 \sum_{\ell=1}^{N-1} V_{K-N+1} \cos (\frac{2\pi}{N} \ell 1) \tag{2.5}$$

where V_i are the voltage samples and N is the number of samples taken per fundamental cycle and 1 is variable.

From Eqs. (2.4) and (2.5) we get the expression for voltage

$$V = [V_s^2 + V_c^2]^{1/2} \tag{2.6}$$

and the phase angle is given by

$$\phi_V = \tan^{-1} (V_s/V_c) \tag{2.7}$$

Similarly for current signal,

$$I = [I_s^2 + I_c^2]^{1/2} \tag{2.8}$$

and

$$\phi_I = \tan^{-1} (I_s/I_c) \tag{2.9}$$

Finally, the expression for the impedance is,

$$Z = |Z| \angle \phi_z \tag{2.10}$$

where,

$$Z = \left[\frac{V_s^2 + V_c^2}{I_s^2 + I_c^2} \right]^{1/2} \tag{2.11}$$

$$\phi_z = \tan^{-1} (V/I) \tag{2.12}$$

If the calculated value of Z and ϕ_z using equations (2.11) and (2.12) exceed the setting, this determines the relaying action. This comparison can be used to perform distance impedance relaying function.

It should be noted that, theoretically, this method promises the best accuracy because it utilizes the fundamental components only and all other components are rejected. This, of course, assumes that the data are available for full power cycle. To improve the time response of the algorithm is to reduce the data window to one half of a cycle [30], which changes the limit on the expressions(2.4) and (2.5).

This introduces additional error due to DC offset and high harmonics, but the scheme can be made quite acceptable by using various methods for compensation of error sources [30]. The one half cycle scheme is particularly efficient computationally when 12 samples per cycle are used because of certain symmetries of the fourier coefficients. A sinusoidal curve fit could be performed where incoming data are used directly to calculate the apparant resistance and reactance to the fault. Samples of voltages and currents are used to perform the fundamental sinusoidal component fit [31]. Similar methods can be applied to calculate peak value of voltage and current [32] as well as power flow, which can then be used to perform relaying function.

2.4.3 Transmission Line Protection Based on the Signal Containing both Fundamental and Transient Frequencies:

This scheme employs two basic techniques. One assumes that the signal can be modeled with an expression containing both fundamental signal and high frequency components. The assumed expression contains unknown parameters which can be determined by a least square estimation technique. Incoming samples are used for the fitting process. Yet another technique uses waveforms which are obtained directly from the transmission lines and contains high frequency components. These are travelling waves which can be obtained as a

solution of distributed parameter (differential) equation used as transmission line model.

The least square technique can be applied to obtain fairly good estimates, assuming a waveform which contains both decaying DC offset and harmonic components [33]:

$$K_1 e^{-\lambda t} + \sum_{m=1}^{N} [K_{2m}\sin(m\omega t) + K_{2m+1}\cos(m\omega t)] \tag{2.13}$$

where $K_1, K_2 \ldots K_{2N+1}$ are unknown parameters, N is the number of harmonics to be considered, λ is the decay constant of the offset and ω is the angular frequency.

Then the least square fit involves minimization of the expression

$$E = \int_0^T I - K_1 e^{-\lambda t} - \sum_{m=1}^{N} [K_{2m}\sin(m\omega t) + K_{2m+1}\cos(m\omega t)]^2 \tag{2.14}$$

where I is the waveform to be analyzed and T is the sampling period. The solutions of the minimization procedure are the unknown parameters K_r, $r = 1,2,\ldots 2N+1$. It should be noted that least square technique mentioned above are computationally quite involved and their accuracy is dependent on the data window applied as well as on the number of samples per cycle [29].

The travelling wave method usesas the basic model the well known telegraph equation (known as wave equation for lossless line) for distributed parameter transmission line

$$-\frac{\partial v}{\partial x} = L\frac{di}{dt} \tag{2.15}$$

$$-\frac{\partial i}{\partial x} = C\frac{dv}{dt} \tag{2.16}$$

Solution of the above equations are of the form

$$v(x,t) = \phi^{+}(x-\alpha t)-Z\phi^{-}(x+\alpha t) \tag{2.17}$$

$$i(x,t) = \phi^{+}(x-\alpha t)+\phi^{-}(x+\alpha t) \tag{2.18}$$

where L is the series inductance per unit length, C is the shunt capacitance per unit length, $Z = (L/C)^{1/2}$ the line surge impedance and $\alpha = (LC)^{-1/2}$ the velocity of propogation. The function ϕ^{+} and ϕ^{-} represent travelling waves which moves in the positive and negative directions respectively. However, a number of techniques are developed for operation of relay.

One approach can be based on detection of the instantaneous change in voltage and current signal at the moment of fault. A particular discriminant function can be developed which is invariant with respect to the location of fault relative to the relay terminals.

2.5 DISCUSSIONS ALONG WITH CONCLUDING REMARKS ON RELAYING ALGORITHMS

Comparison of the line protection algorithm has been done on a very limited scale and there is only one study that gives reasonably extensive results[29]. It was concluded [29] that, in general, any of the algorithms is perfectly accurate when the assumptions from which it is generated are considered. However, the algorithms that are based on the gross and simple assumptions about the faulted waveforms are least accurate. Also, generally, the smaller the data window is, the larger the errors are. Finally, the differential equation algorithms performed quite accurately after approximately one half of a cycle of data used. The Fourier transform algorithms are the most accurate after one cycle of the available data. The travelling wave algorithms have very quick response down to several milliseconds and are quite accurate, particularly when data are obtained from both terminals of the line.

In this thesis, the algorithms used for the proposed digital transmission line protection schemes using Microprocessor, are based on:

a) Predictive calculation of peak value (voltage and current).

b) Extraction of the fundamental component using Fourier transform techniques taking data window equal to one-half the power cycle.

CHAPTER 3

MICROPROCESSOR BASED PROPOSED RELAYING SCHEMES

3.1 SUMMARY

In this chapter, the proposed methods based on two different approaches for impedance calculation for distance type protection suitable for on-line microprocessor protection of transmission lines are outlined. The software realisation of the schemes along with the computation times for implementation in real time are also given.

3.2 PROPOSED RELAYING SCHEME BASED ON THE PREDICTIVE CALCULATION OF PEAK FAULT CURRENT AND VOLTAGE

The method of transmission line protection in this scheme is based on predictive calculation of peak fault current and voltage from small number of samples. The peak values of current and voltage are estimated numerically, from these the transmission line impedance is calculated and fault condition detected.

3.2.1 Mathematical Formulation

The method of calculation of line impedance involves the predictive calculation of peak current and peak voltage, the impedance being determined by division of peak voltage by peak current [20]. A digital computer sampling , a sinusoidal waveform, can determine the peak as they occur.

However, it is necessary in the interest of time to determine the peak value before their occurance i.e. to predict the peak value of the waveform from the given samples.

Let us consider a sinusoidal function,

$$v = V_{pk} \sin\omega t \tag{3.1}$$

where V_{pk} is the unknown (peak voltage) quantity and v is a typical sample value, ωt is also unknown. Taking the derivative of(3.1)w.r.t. time we get,

$$v' = \omega V_{pk} \cos \omega t \tag{3.2}$$

where v' is determined using the numerical technique as detailed in appendix C.

From the equation (3.2) we get,

$$\frac{v'}{\omega} = V_{pk} \cos\omega t \tag{3.3}$$

Squaring eqs. (3.1) and (3.3), and adding we get,

$$V_{pk}^2 = (v)^2 + (\frac{v'}{\omega})^2 \tag{3.4}$$

Dividing equation (3.1) by eq. (3.3) we get,

$$\frac{v\omega}{v'} = \frac{V_{pk} \sin\omega t}{V_{pk} \cos\omega t}$$

$$\tan\omega t = \frac{v\omega}{v'}$$

$$\omega t = \tan^{-1} [\frac{v\omega}{v'}]$$

Thus point on cycle of voltage sample

$$V_\theta = \text{arc tan } [\frac{v\omega}{v'}] \quad (3.5)$$

Similarly for the current, we can get (refer to the eq.(3.4)),

$$I^2_{pk} = (i)^2 + (\frac{i'}{\omega})^2 \quad (3.6)$$

$$I_\theta = \text{arc tan } [\frac{i\omega}{i'}] \quad (3.7)$$

Impedance is calculated by dividing the equation (3.4) by the equation (3.6) and hence we get,

$$Z^2 = \frac{V^2_{pk}}{I^2_{pk}} \quad (3.8)$$

Angle of impedance is obtained by subtracting equation (3.7) from the equation (3.5); hence, we get,

$$Z_\theta = V_\theta - I_\theta \quad (3.9)$$

The possible existence of an exponentially decaying d.c. transient on the current and voltage signal of a high voltage system is not taken into account in the impedance calculation as the offset d.c. component is negligible because if an ideal CT (having mimic impedance) connected to a secondary burden having the same X/R ratio as the primary circuit, then the voltage across the burden will be purely sinusoidal [47]. However, exact cancellation of d.c. offset is not possible for all faults. The primary X/R ratio to be matched

is that of source plus transmission line upto the fault point, and since, in general, the source X/R is not equal to the line X/R, the overall primary X/R is a variable quantity, dependent on how far along the line the fault occurs. This problem can be avoided by matching the secondary burden to the primary X/R composed of the source plus, say 90% of line impedance. It is for faults near the end of the line (i.e. near the balance point) that the most accurate impedance calculations are required for discrimination purposes and for these faults, the transient component will be almost completely removed. For faults closer in, offset will be drastically reduced but not entirely removed.

Sampling rate is a variable, but it has been taken in this case, as 40 samples per cycle, i.e. 0.5 ms between two samples, as this gives a maximum error, in V_{peak} at t_o on a 50 Hz system, of 0.15 percent (refer appendix B for details). This shows that numerical errors are at least small in theory.

3.2.2 General Principle of Relay for Phase Faults:

The principle used in the proposed protective scheme for phase faults is that once the disturbance in impedance is detected, the type of fault (phase or ground) is determined and a suitable single phase relaying quantities such as voltage and current are chosen for impedance calculation. Two continuous signals, one line to line voltage or line to

ground voltage and line current are sampled sequentially at predetermined sampling rate i.e. 40 samples per cycle.

Fault detection is performed by comparing the latest voltage sample to the corresponding sample of the previous cycle. If the value differs in excess of a tolerance limit 5%, the counter is incremented. If the value of the counter is equal to five, the routine jumps to fault detection zone. If the comparision of the voltage samples yield a difference less than above tolerance,
the counter is decremented, if it is not already zero.

3.2.3 Calculation of Impedance:

On occurance and subsequent detection of fault, the program calculates voltage and current derivatives and finally, calculate the V_{peak}, I_{peak}, impedence and angle of impedance using the equations (3.4) - (3.9).

3.2.4 Software Realisation:

In the proposed relaying scheme for phase faults, a RESTRICTED MHO characteristics has been realized and simulated on intel 8080 microcomputer taking 40 samples per cycle.

For testing on Microcomputer, data has been generated using symmetrical component for the sample power network as given in the Appendix D. The algorithm used to simulate

the proposed scheme for phase faults is given below in sequence.

1. Intialize all the registers of CPU, counters etc.
2. Store the constants pertaining to relay characteristics such as set impedance, look up table for arctan.
3. Take samples.
4. Cycle by cycle comparision of voltage samples is carried out and accordingly, the counter is incremented, if, the difference in the two voltage samples is more than the specified value or otherwise decremented, if not, already zero. If the value of the counter is move than 5, fault determination starts, else go to step 3.
5. Calculate derivatives of voltage and current using numerical technique given in Appendix C.
6. Calculate V_{peak} and I_{peak} using equations(3.4) and (3.6)
7. Calculate the impedance using equation (3.8) and determine argument of impedance from the look up table of arc tan stored in the memory.
8. Check whether $0 < Z_{\theta} < 90$ else go to step 3.
9. Check whether $Z_R \cos(\phi - \theta) \geq Z_c$, else go to step 3.
10. Initiate tripping signal.

The sampling is continued throughout the calculation stage and the samples are stored in the appropriate memory location by hardware arrangement discussed in the section later.

3.2.5 Results alongwith Discussions:

1. With the proposed algorithm the estimation of V_{peak} and I_{peak} are accurate to ± 09%, the impedance modulus to within ± 10% and argument of impedance to within 5°. Fig. 3.1 shows the characteristic of proposed algorithm, which is obtained by keeping angle $\emptyset$ of Z_R fixed and for a particular angle of fault impedance, the impedance is found out where the tripping occurs and the theoretical characteristics from where it is seen that the actual characteristics is very near to the theoretical one.

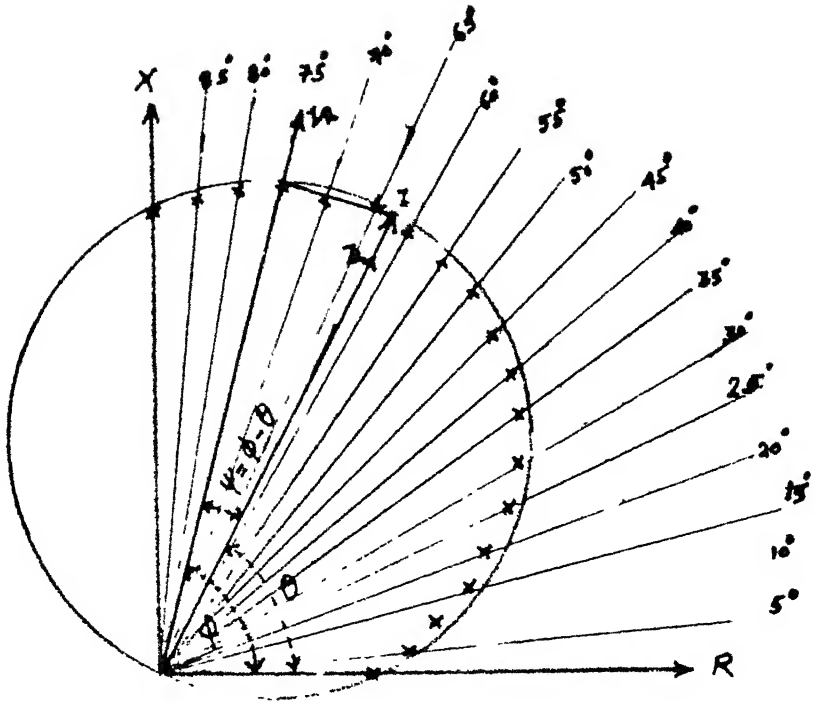
2. The operating time of the proposed relaying scheme for phase faults is approximately equal to 4.44ms for zone 1 operation, 15.18 ms for zone 2 operation and 25.44ms for zone 3 operation, which are sum of

   a) time required to acquire 5 samples for detection of disturbance which is 2.0 ms

   b) time required for calculation of impedance and angle of impedance and computation time required to satisfy restricted Mho characteristics which is 1 8-7 cycles (2.44ms) for zone 1, 13438 cycles (2.68ms) for zone II operation, 14701 cycles (2.94ms) for zone III operation

3. Timing details at various stages is given in the flow chart. (See Fig. 3.2).

4. The program listing is attached in Appendix E.



xxx CHARACTERISTIC OF PROPOSED ALGORITHM
— THEORITCAL CHARACTERISTIC

FIG3·1 RESTRICTED MHO'S RELAY CHARACTERISTIC

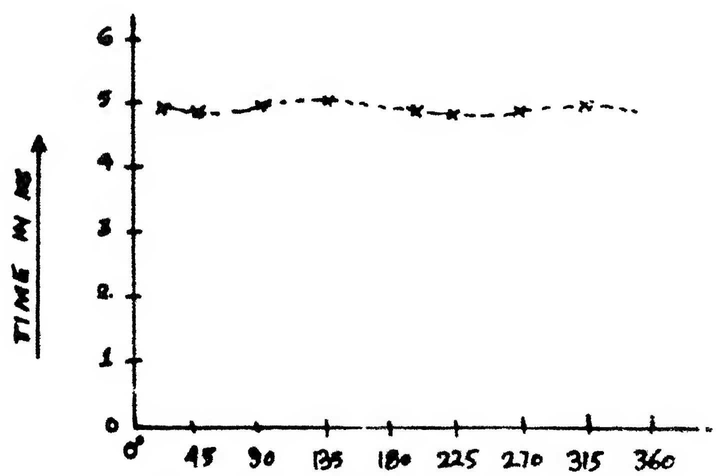


FIG3·2A: OPERATING CHRACTERISTIC OF R. MHO RELAY

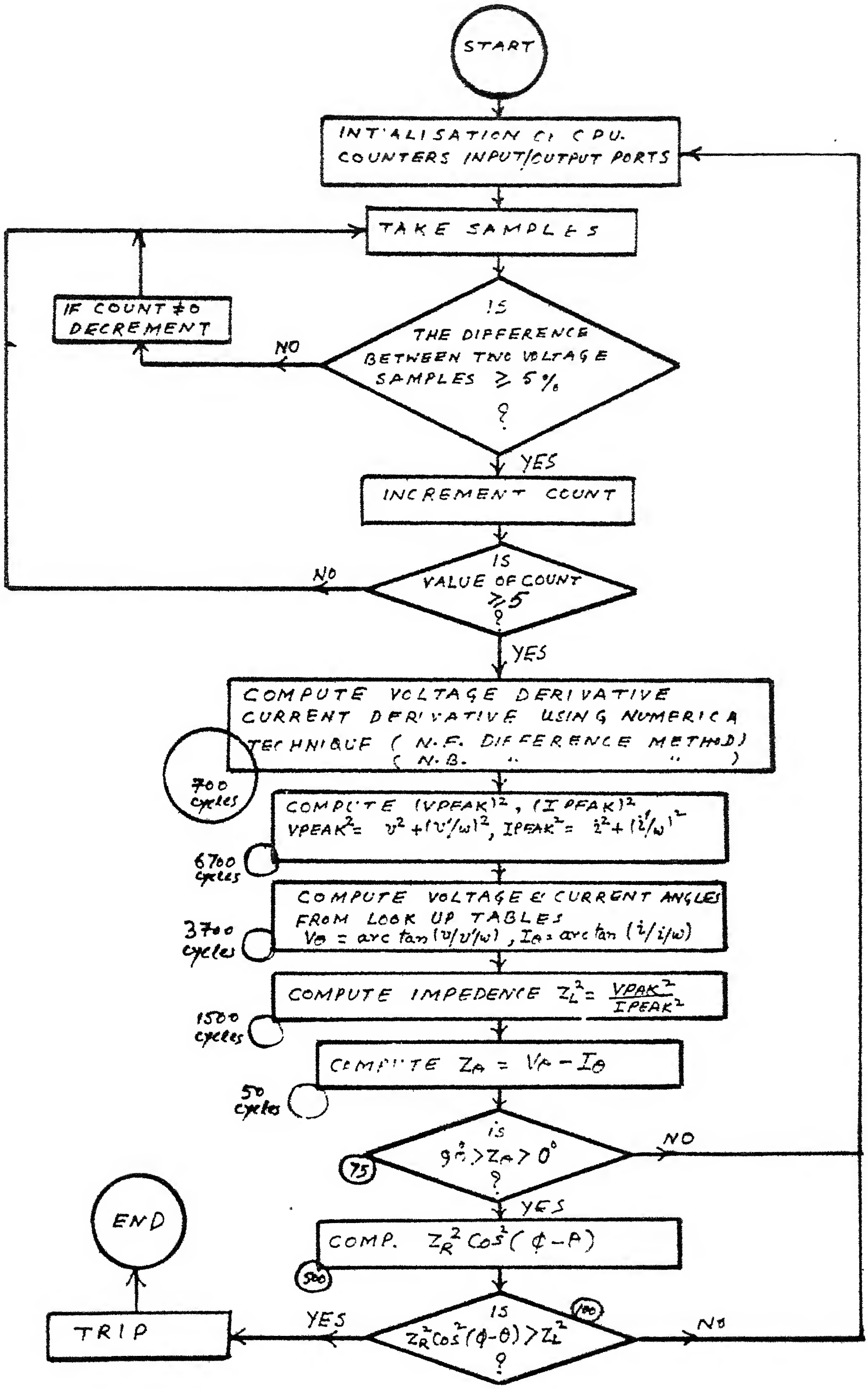


FIG 3.2: FLOWCHART: PROPOSED REAL TIME ALGORITHM FOR RESTRICTED MHO CHARACTERISTIC

5. The complexity of calculation has been reduced by converting the essentially parallel operation of analogue relays into serial digital computations. Also no data from healthy phases is involved in the calculation of impedance. This has necessitiated the development of a protective scheme which, upon detection of a disturbance, isolates the phase involved and selects an appropriate set of relaying current and voltage for subsequent impedance calculation.

6. The operating time vs switch angle of fault current is given in Fig. 3.2A.

3.3 PROPOSED RELAYING SCHEME BASED ON FUNDAMENTAL COMPONENT TAKING DATA WINDOW EQUAL TO ONE-HALF POWER CYCLE

The proposed relaying scheme is based on the extraction of fundamental frequency component from the input signal, using Fourier transform theory and assuming that data are available for half of the power cycle.

3.3.1 Mathematical Formulation:

Distance fault locating digital algorithms are often based on the processing of fundamental components which are contained in the currents and voltages. If the extraction of these components is done by means of correlating the signal with sine and cosine function of the fundamental frequency, and the data window is shorter than one cycle, the

presence of aperiodic components in the signal gives rise to large error. To minimise the error in calculating the fundamental component for a data window equal to half cycle, the signals ought to be correlated with sine/cosine functions which have periods equal to the data window length [34].

Let current and voltage input signals are represented by,

$$I_{(t)} = I_1 \cos(\omega_1 t - \alpha) + I_a\, e^{-t/\tau_a} + I_p\, e^{-t/\tau_p} \cos(\omega_p t - \gamma) \tag{3.10}$$

$$V_{(t)} = V_1 \cos(\omega_1 t - \alpha + \varphi) + V_a\, e^{-t/\tau_a} + V_p\, e^{-t/\tau_p} \cos(\omega_p t - \beta) \tag{3.11}$$

First terms of the right hand side of the equations (3.10) and (3.11) are steady state fundamental components. The second terms are well known aperiodic (i.e. DC) components decaying with time constant τ_a which to a certain degree random factor like for example, a fault resistance. The third term represents decaying oscillations induced by the fault. The decaying time constant τ_p varies and has been assumed to be equal to infinity, being the worst case. Amplitude of transient components depend on the nature of signal and, it is the transient components, which make the greatest source of error in the process of fault location. When the

data window is less than one period, the transient component becomes higher, thus increasing the overall error substantially. Therefore, the real and imaginary parts of voltage and current is calculated for the angular frequency of ω_2 correspondin to data window at which the spectrum of aperiodic component reaches minimum.

The real and imaginary parts of fundamental component of voltage and current are,

$$V_1 = V_d + jV_q \tag{3.12}$$

$$I_1 = I_d + jI_q \tag{3.13}$$

Since the signal is being processed in certain time span T_ω , called data window, the shifted time scale is introduced into the formula of signal. This makes the middle of the window always coincide with 0 of the new time variable τ.

Let, $\tau = t - (t_1 + \frac{T_\omega}{2})$ where t_1 is the begining of the data window.

According to Fourier transform theory and correlating the signal with sine/cosine functions which have period equal to data window T_ω i.e. $\omega_2 = \frac{2\pi}{T_\omega}$, we have,

$$V_d = \frac{K}{T_\omega} \int_{t_1}^{t_1+T\omega} V_{(\tau)} \cos \omega_2\tau \; d\tau \tag{3.14}$$

$$V_q = \frac{P}{T\omega} \int_{t_1}^{t_1+T\omega} V_{(\tau)} \sin \omega_2\tau \ d\tau \qquad (3.15)$$

$$I_d = \frac{K}{T\omega} \int_{t_1}^{t_1+T\omega} I_{(\tau)} \cos \omega_2\tau \ d\tau \qquad (3.16)$$

$$I_q = \frac{P}{T\omega} \int_{t_1}^{t_1+T\omega} I_{(\tau)} \sin \omega_2\tau \ d\tau \qquad (3.17)$$

where coefficients K and P [34] are

$$K = \frac{\pi(1-r^2)}{r\sin\pi r}$$

$$P = \frac{-\pi(1-r^2)}{\sin\pi r}$$

and $r = \frac{\omega_1}{\omega_2}$

ω_1 = normal power frequency of 50 hertz

ω_2 = angular frequency corresponding to data window.

Taking data window equal to half the period i.e. half cycle, i.e., $T\omega = \pi/\omega_1$, the coefficient K and P can be written as,

$$K = \frac{3\pi}{2} \quad , \quad P = -\frac{3\pi}{4} \qquad (3.18)$$

Equation (3.14) to equation (3.17) can be written as,

$$V_d = \frac{3\pi}{2T\omega} \int_{t_1}^{t_1+T\omega} V_{(t)} \cos \omega_2(t-t_1-\frac{T\omega}{2}) \ dt \qquad (3.19)$$

$$V_q = \frac{-3\pi}{4T\omega} \int_{t_1}^{t_1+T\omega} V_{(t)} \sin \omega_2 (t-t_1- \frac{T\omega}{2})dt \qquad (3.20)$$

$$I_d = \frac{3\pi}{2T\omega} \int_{t_1}^{t_1+T\omega} I_{(t)} \cos \omega_2 (t-t_1- \frac{T\omega}{2})dt \qquad (3.21)$$

and,

$$I_q = \frac{-3\pi}{4T\omega} \int_{t_1}^{t_1+T\omega} I_{(t)} \sin \omega_2 (t-t_1- \frac{T\omega}{2})dt \qquad (3.22)$$

The solution of the above equations (3.19-3.22) have been obtained using numerical techniques as given in the Appendix A and the final results obtained are as shown below.

$$V_d = A[V_{(t_1)} \cos\pi - 2V_{(t_2)} \cos\frac{2\pi}{N} - 2V_{(t_3)} \cos \frac{4\pi}{N} -$$

$$\ldots - 2V_{(tN)} \cos \frac{(N-1)2\pi}{N} + V_{(tN+1)} \cos\pi]$$

$$V_q = A[V_{(t_1)} \frac{\sin\pi}{2} + V_{(t_2)} \sin \frac{2\pi}{N} + V_{(t_3)} \sin \frac{4\pi}{N} +$$

$$\ldots + V_{(tN)} \sin \frac{(N-1)2\pi}{N} - V_{(tN+1)} \frac{\sin\pi}{2}]$$

$$I_d = A[I_{(t_1)} \cos\pi - 2I_{(t_2)} \sin \frac{2\pi}{N} - 2I_{(t_3)} \sin \frac{4\pi}{N} -$$

$$\ldots - 2I_{(tN)} \cos \frac{(N-1)2\pi}{N} + I_{(tN+1)} \cos\pi]$$

$$I_q = A[I_{(t_1)} \frac{\sin\pi}{2} + I_{(t_2)} \sin \frac{2\pi}{N} + \sin \frac{4\pi}{N} +$$

$$\ldots + I_{(tN)} \sin \frac{(N-1)2\pi}{N} - I_{(tN-1)} \sin \frac{\pi}{2}] \qquad (3.23)$$

where N is the number of intervals a over a sampling period.

3.3.2 Fault Locating Algorithm:

The impedance seen by the relay is obtained by dividing the peak of voltage by the peak of current i.e. the expression for the impedance is,

$$Z = \frac{V_d + jV_q}{I_d + jI_q}$$

$$= \frac{(V_d+jV_q)(I_d-jI_q)}{(I_d+jI_q)(I_d-jI_q)}$$

$$Z = \frac{V_dI_d+V_qI_q}{I_d^2 + I_q^2} + j\,\frac{V_qI_d-V_dI_q}{I_d^2 + I_q^2} \qquad (3.24)$$

But, $Z = R + jX$

Therefore, we get,

$$R = \frac{V_dI_d+V_qI_q}{I_d^2 + I_q^2}$$

$$X = \frac{V_qI_d-V_dI_q}{I_d^2 + I_q^2} \qquad (3.25)$$

3.3.3 Principle of Relay Operation for Phase Faults:

The principle underlying the proposed scheme is, that, the two continuous signals one, line to line voltage or line to ground voltage and second, line current are sampled sequentially at a predecided sampling rate, say 12 samples per cycle.

Fault detection is performed by comparing the latest voltage sample to the corresponding sample of the previous cycle. If the values differ in excess of a tolerance limit 5%, the counter is incremented. If the value of the counter is equal to seven (in this case) the routine jumps into the fault determination routine (see flow chart).

If the comparision of the voltage samples yield a difference less than 5% i.e. comparison is healthy, the counter is decremented, if it is not already zero.

3.3.4 Calculation of Resistance and Reactance:

On detection of disturbance i.e. when counter value is equal to seven (for the present case), the program starts calculating R and X using the equation (3.25) and finding whether the fault has occured or not. The incoming signals during this period are stored in the appropriate memory locations.

3.3.5 Software Realisation:

Since quadrilateral characteristics is the best threshold characteristic available for the protection of EHV/UHV heavily loaded long lines as it encloses the fault area compactly and therefore, possesses the valuable properties of least tendency for maloperation under heavy power swings and also greatest immunity to under reaching

tendencies arising out of fault resistance. In the proposed relaying scheme for phase faults, a quadrilaterial characteristics has been realized and simulated on INTEL 8080 microcomputer at IIT Kanpur taking 12 samples per cycle i.e. 6 samples per half cycle as data window is taken as half the power cycle (i.e. $T\omega = 1/2\ T_1$).

For testing on microcomputer, data has been generated using symmetrical components (see Appendix D, for sample power system network as given in the appendix D).

The algorithm used to simulate the proposed relaying scheme for phase faults is given below with reference to the flow chart.

1. Initialize all the register of CPU, counters etc.
2. Store the constant pertaining to relay characteristics such as sine and cosine table, K_1, K_2.
3. TAKE SAMPLES
4. Cycle by cycle comparison of voltage sample is carried out and accordingly by the counter is incremented if difference between two voltage sample is more than specified value or otherwise decremented if not already zero. If the value of counter is more than seven, fault detection starts, else Go to Step 3.
5. Calculate V_d, V_q, I_d and I_q using the equation (3.17-3.22) developed for data window $T\omega$ equal to half the power cycle.
6. Calculate R and X using equation (3.25).

7. Check whether $X \geq 0$ if YES continue else go to step 3.
8. Check whether $R \geq 0$ if YES continue else go to step 3.
9. Check whether $R \leq R_3$ if YES continue else go to, step 3.
10. Check whether $R \leq R_2$ if YES continue else go to step 13.
11. Check whether $R \geq R_1$ if YES continue else go to step 14.
12. Initiate the tripping signal
13. Check whether $K_4 \geq K_2$ if YES go to Step 12 else go to step 3.
14. Check whether $K_3 \leq K_1$ if YES go to step 12 else go to step 3.

3.3.6 Results and Discussions:

1. Since numerical integration is used and there is error in calculating R and X Fig. 3.3. shows the characteristics of the proposed algorithm and the theoretical characteristic, from where it can be seen, that the proposed characteristic is very close to the theoretical one.

2. The operating time of proposed relaying scheme for phase fault is approximately equal to 16.23 ms for Zone 1, 21.62 ms for Zone 2 and 26.85 ms for Zone 3, which is sum of the

a) time to acquire necessary data i.e. in this case it is 10 ms.

b) time required for calculation of R and X and computing time required to satisfy quadrilateral characteristic which is in our case is 31026 cycle, for zone 1, 33125 cycle for zone 2 operation, 34255 cycle for zone 3 operation

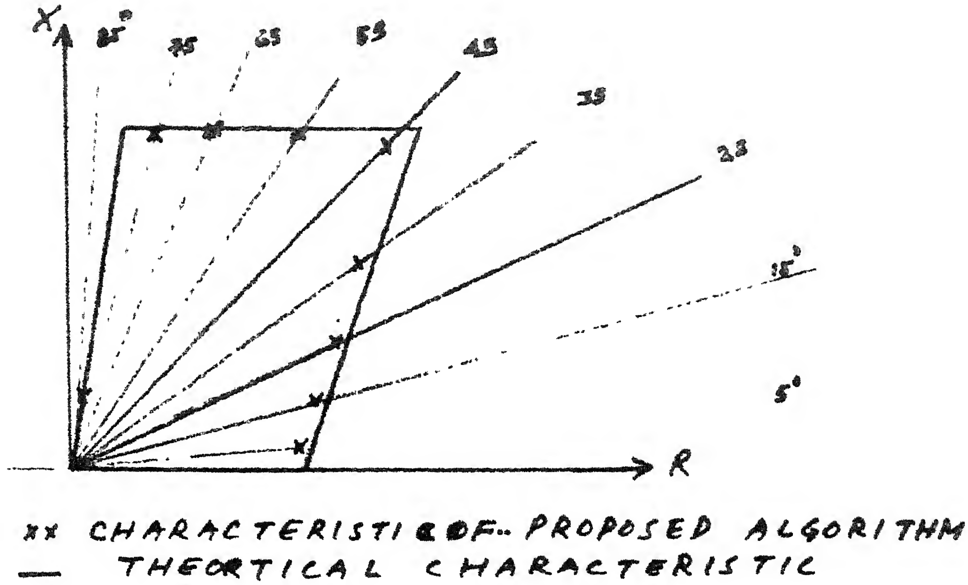


FIG 3·3 : QUADILATERAL CHARACTERISTIC OF THE PROPOSED RELAYING SCHEME

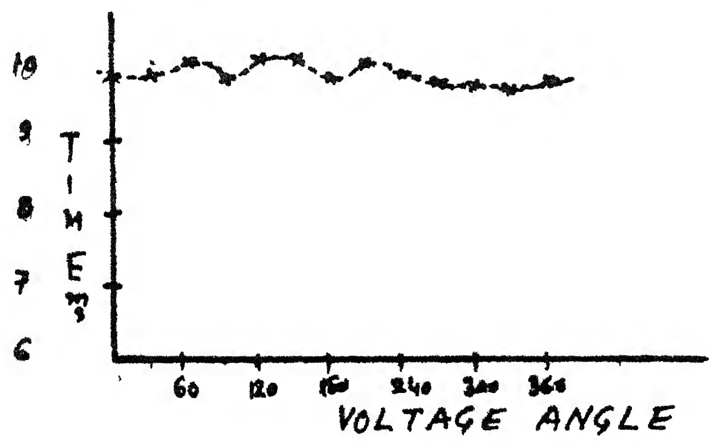


FIG 3·3A: OPERATING CHARACTERISTIC

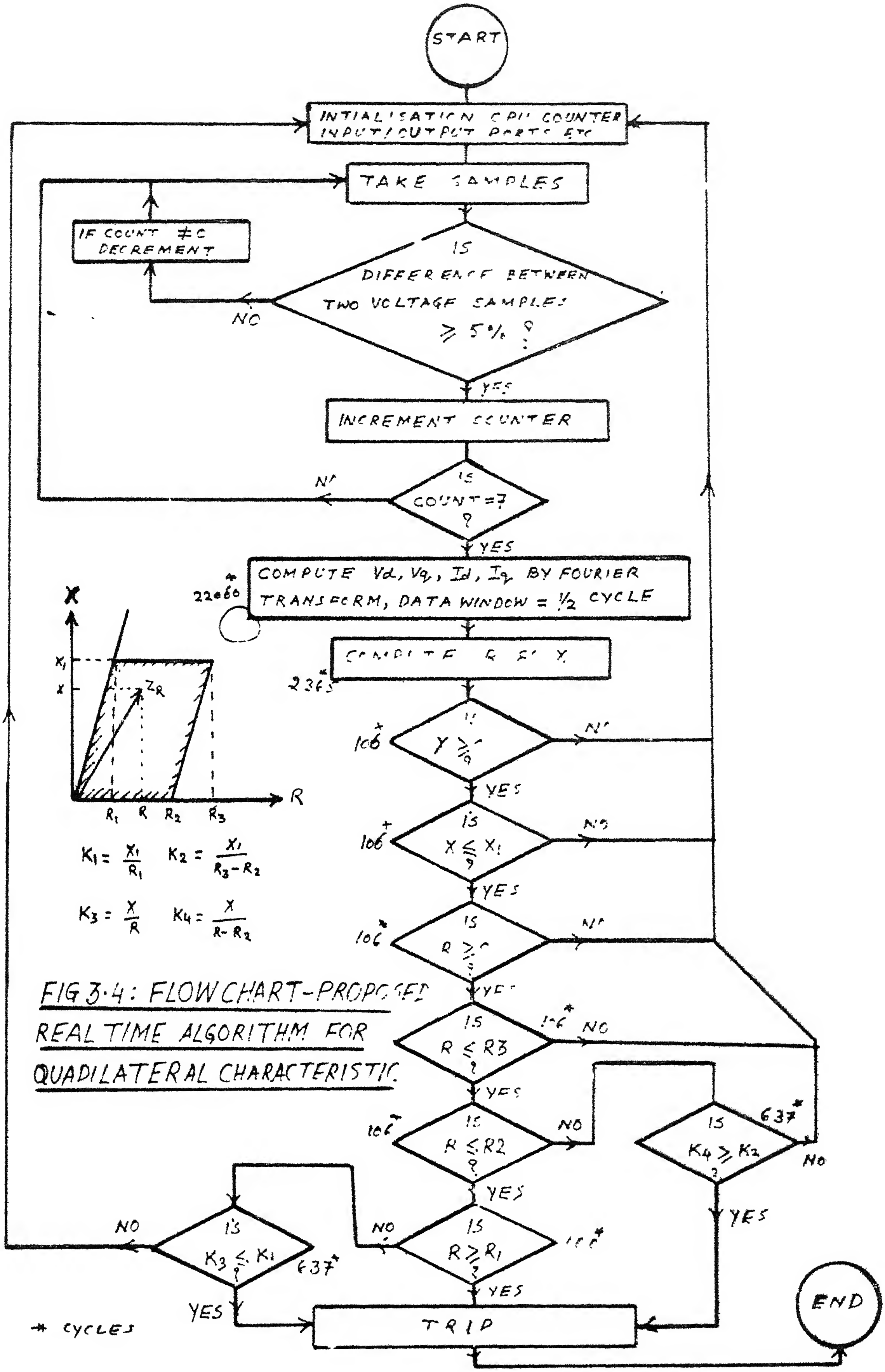


FIG 3.4: FLOWCHART-PROPOSED REAL TIME ALGORITHM FOR QUADILATERAL CHARACTERISTIC

3. Various calculation time is given in the flow chart. (See Fig. 3.4).

4. The program listing is attached as Appendix F.

5. The operating characteristic plotted between operating time and fault incidence angle is given in Fig. 3.3A.

CHAPTER 4

HARDWARE REALISATION OF PROPOSED RELAYING SCHEMES FOR ON LINE PROTECTION OF TRANSMISSION LINES USING MICROPROCESSOR

4.1 SUMMARY

This chapter deals with the design, development and testing of microprocessor based relaying scheme. The decentralized approach has been used for the hardware realization of the proposed relaying scheme as outlined in the previous chapter.

4.2 DIGITAL RELAYING SCHEMES

Based on the hardware implementation, we can divide the protection system developments into three categories.

a) Centralized approach

b) Decentralized approach

c) Integrated approach

4.2.1 Centralized Approach:

It covers implementation which uses only one mini-computer to accomodate most of the protection systems. The first digital relaying (prototype) system PRODAR 70, was developed in joint effort by Pacific Gas and Electric Company and the Westinghouse Electric Corporation in 1971 [35]. The system was minicomputer-based and all of the basic

protection functions found in a typical high voltage substation were implemented. For several years,a number of tests were conducted and the results were published in 1975 [36]. Also in the early 1970s, the American Electric Power Service Corporation (AEP) initiated a joint project with the IBM corporation to develop a minicomputer-based relaying and data acquisition system. This project resulted in a prototype system which was field tested and the results were published in 1976 [30]. In 1973, the General Electric Company (GEC) started a project to develop a minicomputer based distance relay, which was further extended to include a pilot scheme having a digital system at each terminal of the transmission line to be protected. Field tests for this system were completed in 1978 and the results were published in 1979 [37]. Minicomputer-based relay design activities were initiated at the University of New South Wales in early 1970s [46]. In 1976, this design was implemented by the Electricity Commission of New South Wales. The field tests started in 1978 and the results were published in 1980 [39]. Finally, a minicomputer-based protection system to be applied in low voltage substation (110 KV) was developed in Germany by the Siemens Corporation and the test results were reported in 1979 [40]. Obviously, all of the above approaches were of the centralized type since all of the functions were carried out by a minicomputer.

The final conclusions of the projects indicated, that, the idea of centralized protection system was feasible, but in order to achieve a flexible and sufficiently fast relaying function, a very fast and powerful computer system should be considered. This, in turn, implies a quite costly solution to the problem.

The above requirements for the cost-effective solution with superior performance characteristics were achieved with the introduction of microprocessor and the development of micro-computer-based relay. This led to the development of the second basic philosophy in designing digital relaying system, mainly the decentralized approach.

4.2.2 Decentralized Approach:

Microprocessors have been considered for relaying application since 1975 [43]. Several projects have been initiated for the development of transmission line protection system. Prototype system for microprocessor-based distance relay were developed and field tested by the Mitsubishi Electric Corporation and the Kansi Electric Power Company [38], as well as by the Tokyo Electric Company and Toshiba Corporation [42]. A software development for a transmission line protection was reported by the Saskatchewar Power Corporation, Canada [45].

All of the above implementation were based on the concept of decentralized applications. This means that the microprocessor based system were intended to perform only one protection function. The system performed satisfactorily compared to the conventional relays. The reported system were shown to be attractive, both cost wise as well as performance wise, when compared to the conventional system. However, most of the reports related to the microcomputer - based relays were published during the period 1977-1979 and there are very few papers published on their actual field testing.

4.2.3 Integrated Approach:

In this case, the protection system functions are distributed to a number of microprocessors which are then connected in an integrated manner. There are two basic types of integrated system.

a) Integrated protection systems

b) Integrated control and protection systems.

It should be noted that only one integrated system has been implemented [44] and tested by the Mitsubishi Electric Corporation and Kansai Electric Power Company of Japan. This is of control and protection type. This system was of a very limited scale in terms of the functions that were implemented.

The integrated systems are capable of performing the relaying functions in parallel. Each dedicated microprocessor exhibit performance characteristics which are similar to that of decentralized approach. At the same time, the system integration concept, provides the additional benefits of exclusive data acquisition and monitoring of the overall protective functions. This approach requires only a moderate system price increase when compared with the decentralized approach because of the communication subsystem. The benefits of integrated approach are numerous and include most of the benefits provided by the centralized and decentralized approaches. Some additional performance improvement is expected since the control and protection are combined and can be maintained and operated through a sophisticated man-machine interface. However, the integrated system are still in the proposal phase (state).

In the present work, the decentralized approach is used for the software/hardware system developments for the proposed relaying schemes for the protection of transmission line.

4.3 BLOCK SCHEMATIC DIAGRAM OF THE PROPOSED MICROPROCESSOR-BASED RELAYING SCHEME

A simplified hardware configuration of the proposed relay is shown in the Figure 4.1 as applied for the protection of EHV/UHV transmission line.

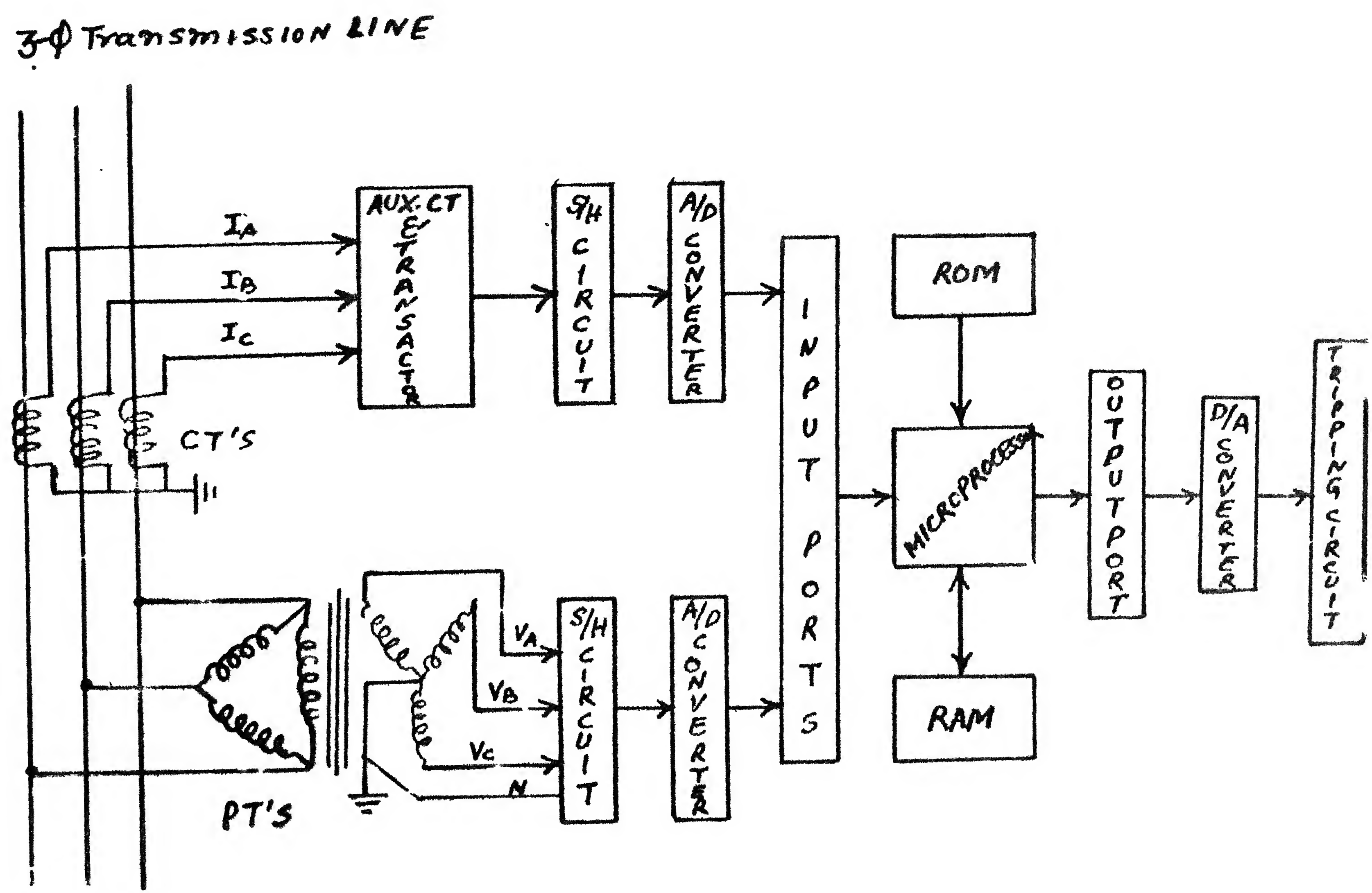


FIG 4.1: BLOCK SCHEMATIC OF THE PROPOSED RELAYING SCHEME

Data acquisition is done by sampling simultaneously the bus voltages and line currents by sample and hold circuits. These signals are converted into the digital form using Analog to digital converters and transmitted to the input ports of the microprocessor. Sampling interval is set by an external oscillator and to maintain the synchronization with the supply frequency phase locked loop (PLL) is used. The advantage of using PLL is that the sampling instant will be exactly same as that of previous cycle. The central processing unit is a microprocessor 8085 AH with a 8 bit word size. The basic cycle time is 200 nsec if crystal oscillator is of 10 MHz or 320 nsec if the crystal oscillator used is 6.144 MHz.

4.4 HARDWARE REALISATION

The relay which has been developed whose schematic diagram is given in Fig. 4.1, is sub-divided into four main sections.

a) Data acquisition system

b) Microcomputer

c) Secondary interface

d) Power supply

4.4.1 Data Acquisition System (DAS):

Data acquisition primarily includes circuits of

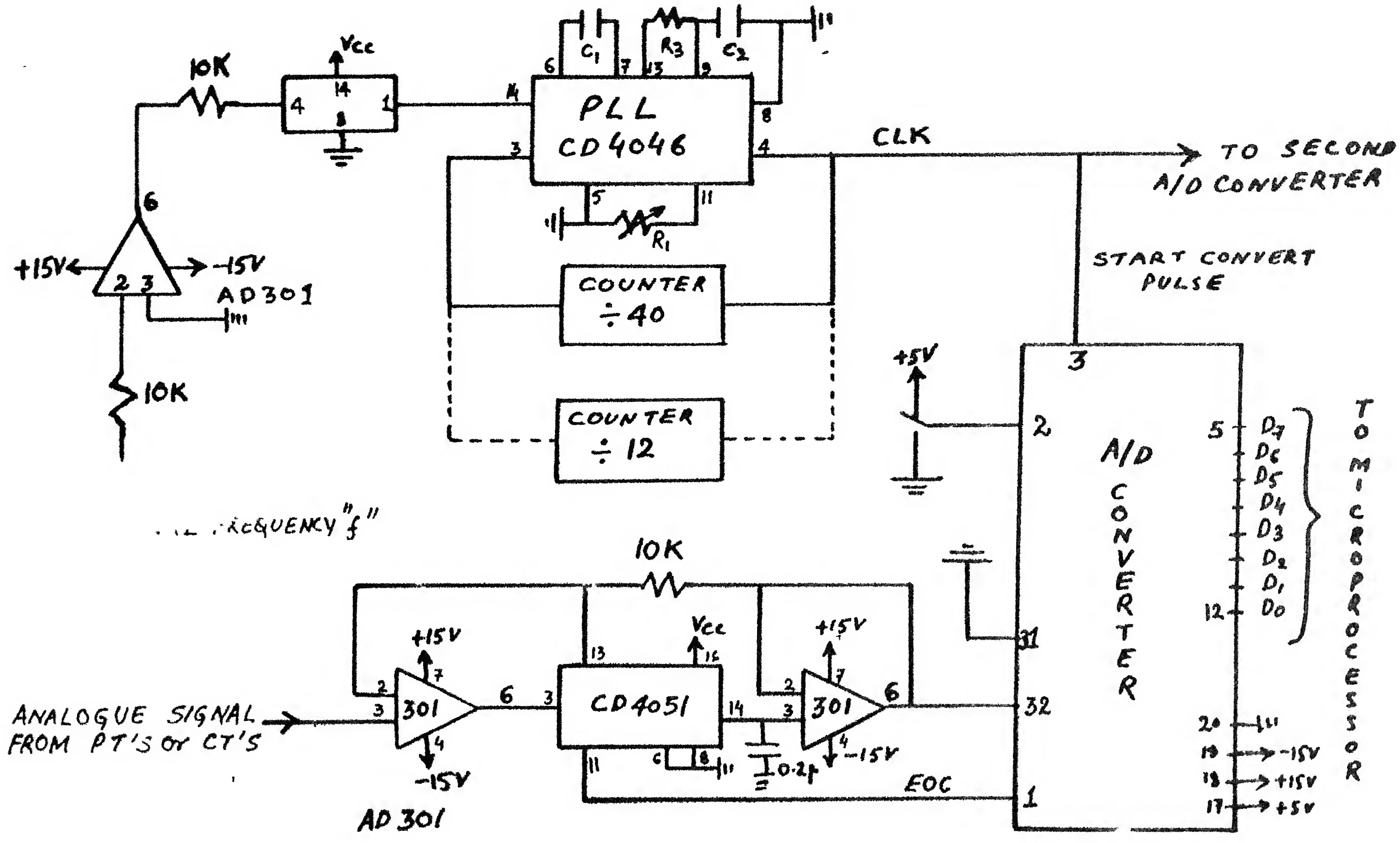


FIG 4.2: BLOCK SCHEMATIC OF DATA AQUISITION SYSTEM

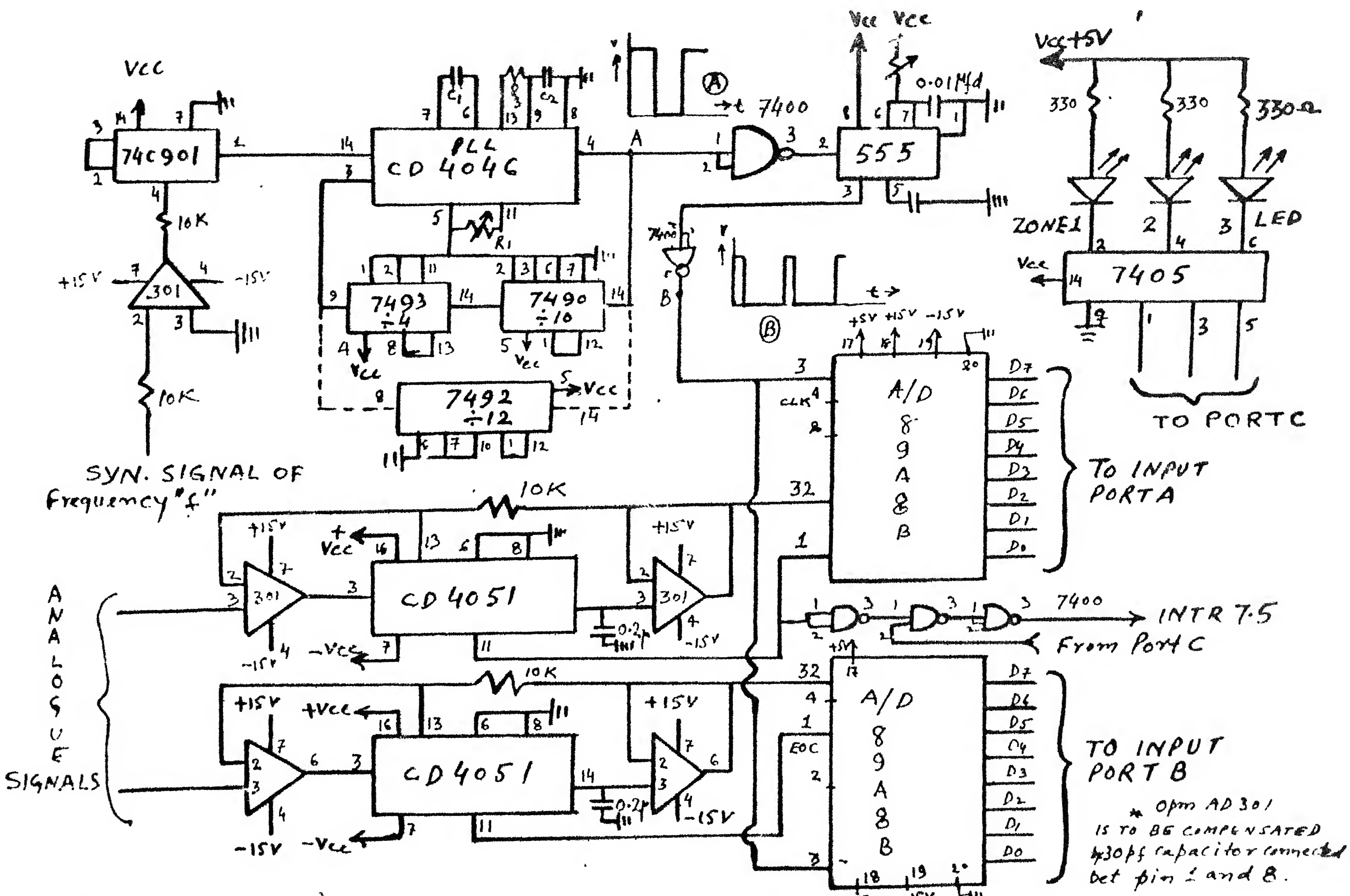


FIG 4·3: CONNECTION DIAGRAM OF DATA AQUISITION SYSTEM

synchronization, Sample/Hold and Analogue to digital converter. The block schematic and connection diagram of data acquisition system is given in Fig. 4.2 and Fig. 4.3 respectively.

The samples are taken at an interval of 0.5 ms i.e. 40 samples/cycle. To achieve this, 2 KHz external oscillator is required. Clock of 2 KHz has been generated using PLL 4046, this clock will always be in synchronism with the supply frequency. The synchronising supply signal is fed to the input of phase lock loop (PLL) after making the output of op-amp. TTL compatible using inverter 74C901. A division by 10 counter and a division by 4 counter are provided in the feedback path of the PLL. These counters serve the purpose of providing a frequency clock (f_{ck} = 40 x f) at the terminals of the voltage controlled oscillator. To achieve a frequency of 600 cycle (12 samples/cycle) as required in the proposed scheme II, a counter divide by 12 is used.

The start convert pulse thus generated using PLL is given to ADC. The positive transition of start convert pulse triggers the ADC to start converting the previous sampled value into equivalent digital form. At the same time, end of conversion (EOC) status is made high putting the sampling circuit in hold mode (i.e. output of SHC is held constant in this period). After completion of the conversion, EOC is made low thereby putting the SHC in sampling mode (i.e. output

of sample and hold circuit changes during this period) and during the same time, digital data can be latched to processor through 8255. Again when the start convert pulse comes, same process is repeated.

4.4.2 Microprocessor Based System:

The circuit diagram of microprocessor (8085A) based system is given in Fig. 4.4. The microprocessor based system consists of microprocessor (8085A) and its associated IC's and the memories. On board, memory consists of EPROM (2716) and RAM (2114), 8255A provides I/O ports, three 16 bit programmable timers are provided using the 8253. The address map is as follows,

RAM	:	(2114x2)	:	1 K bytes
EPROM	:	2716	:	2 K bytes
I/O Ports	:	8255A		
TIMER	:	8253		

The full size double sided PCB has been developed. Sockets have been used for all IC's to avoid trouble later while checking. After inserting the sockets, the jumpers have been wired with the hook up wires. The power supply terminals of the IC's is connected to the +5V and ground points. A 0.01 µfd ceramic capacitor is connected between the supply terminals of the ICs. The

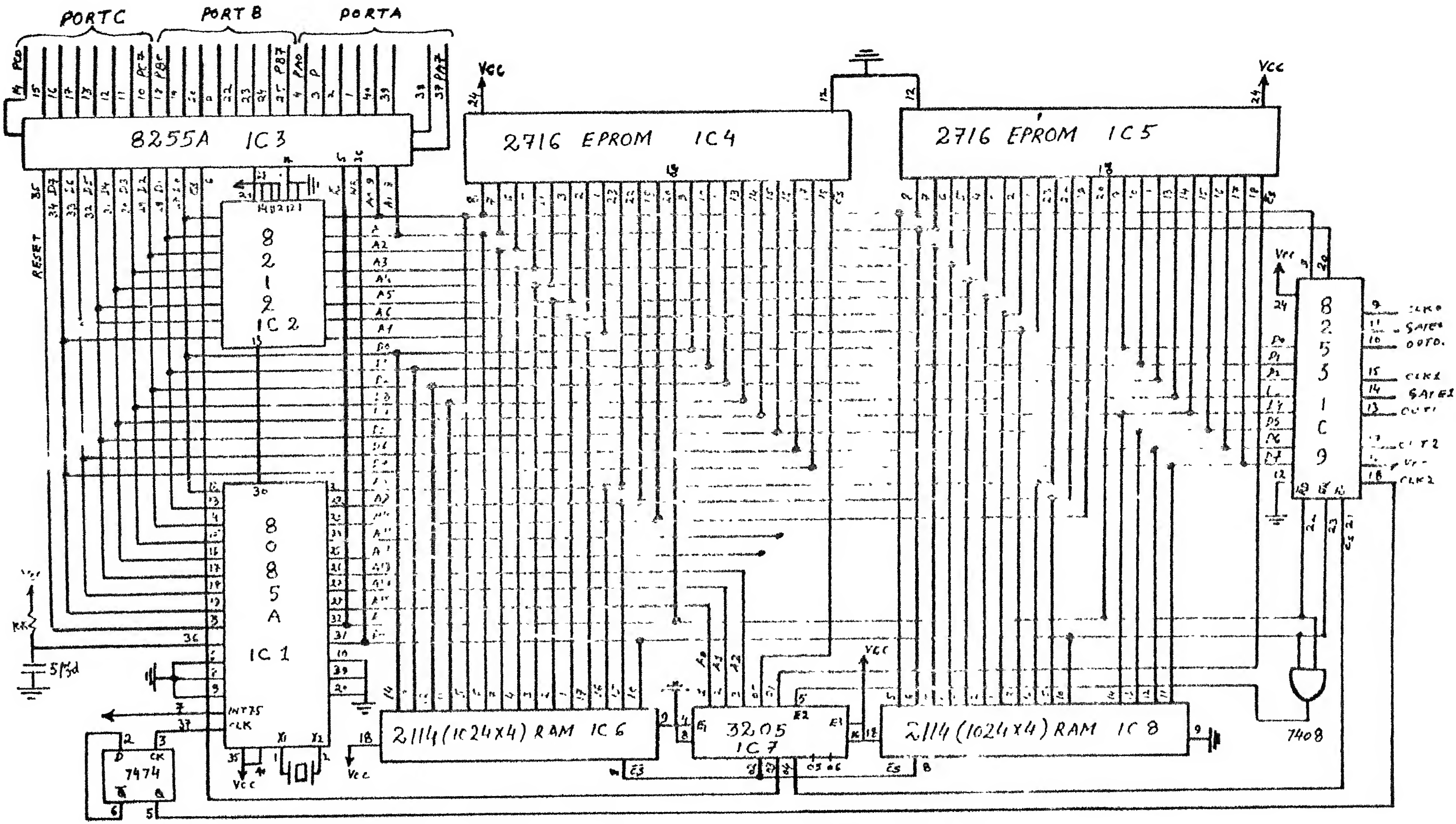


FIG 4.4 CONNECTION DIAGRAM OF MICRO-COMPUTER

6.144 MHz crystal oscillator is soldered between pin 1 and 2 of the microprocessor IC 8085A.

4.4.2.1 Circuit Description:

The 8085A IC is the heart of the circuit. It needs only a single +5V supply for its working. It has built-in timing oscillator and works by connecting a crystal between terminals 1 and 2. The frequency upto which it can be worked is 10 MHz, but in the circuit 6.144 MHz crystal is used. The cycle time is approximately 320 nsecs. The 40 pins of the IC 8085A are for Address lines, Data lines, Serial input and output, interrupt pins, Hold and Hold acknowledge, Resetting input and output as well as status signal for accessing the memory ICs and input/output ports.

The lines AD_0 to AD_7 carry both address and data information together, on a time sharing basis. The moments during which address information is present on the line is synchronously given by the pulse coming from pin 30 - the 'Address Latch Enable' pin (shown as ALE in circuit diagram Fig. 4.4). So, by catching this information at this instant on an 8-bit latch consisting of 8-D flip-flop, the address information is continuously available on the eight output of flip-flops. The 8212 IC is used for this purpose. The input to this, are the lines AD_0 to AD_7. The latched address information A_0 to A_7 comes out as eight lines from

8212. The AD_0 to AD_7 are now useful as Data lines D_0 to D_7 which go to the Data bus.

The address lines A_8 to A_{15} are coming continuously from the pins 21, 22, 23, 24, 25, 26, 27 and 28. In this circuit, all the lines are being used i.e. all 64 K memory is being used, but at present only 2K EPROM and 1K RAM is used. The circuit works in Memory mapped mode.

The control output pins of 8085 are I/O $\overline{M}$ (pin 34), $\overline{RD}$ (pin 32), $\overline{WR}$ (pin 31), S_0 (pin 29) and S_1 (pin 23). The control output pin I/O $\overline{M}$, S_0 and S_1 are not used in the circuit. The $\overline{RD}$ and $\overline{WR}$ signals are low while some data is being read or is written to either a port or a memory location.

The address decoding is done using address decoder IC 8205. The lines A_{13}, A_{14}, A_{15} are given to pin A_0, A_1 and A_2 of IC 8205 i.e. pin No. 1 to 3. To enable the decoder, the output after ANDING $\overline{RD}$ and $\overline{WR}$ using IC7400 (see Fig. 4.4) is given to enabling pin E_2 (pin 5) other enabling pin 4 is grounded and pin 6 (E_3) is connected to +5V V_{cc}. In this way, eight chip select is generated CS_{00} to CS_{07} (pin 15,14,...9 and 7). Thus, the addresses of EPROM, RAM, PPI and counter are as follows:

EPROM1 : CS00 : 0000H-IFFFH: 8K of memory can be address
: 0000H-07FFH: 2K of memory as EPROM1 is of 2K byte.

EPROM2	: CS01	: 2000H - 3FFFH	: Available
		: 2000H - 27FFH	: Actual used
RAM	: CS02	: 4000H - 5FFFH	: Available
		: 4000H - 43FFH	: Actual used
PPI 8255	: CS03	: 6000H - 7FFH	: Available
		: 6000H - 6003	: Actual used
TIMER	: CS04	: 8000H - 9FFH	: Available
		: 8000H - 8002	: Actual used

The other pins of the 8085 which are brought out via edge connector are:

INTR, TRAP, RST 5.5, RST 6.5, RST 7.5 (interrupt pins), clock and Reset out pin.

The five interrupt pins are to be normally kept low i.e. at '0' level and when any of four is made high i.e. 1 level, any programme that is running in the microprocessor is interrupted and execute the next instruction either from a fixed location in the memory (see Table 4.1) or executes a call instruction jammed onto its buses by some external device. The call instruction is executed if INTR lines goes high. When any of these five lines goes high, we say that an interrupt has occured. In the circuit given above in Fig. 4.4, only RST 7.5 is used and rest are grounded permanently.

Table 4.1

Interrupt Restart Location for 8085A

LINE	Location from which next instruction is picked up (HEX address)
TRAP	24
RST 5.5	2C (= 5.5 x 8)
RST 6.5	34 (= 6.5 x 8)
RST 7.5	3C (= 7.5 x 8)

The line RST 7.5 is made high periodically with reference to EOC status of A/D converter, only during the period the processor is engaged in calculation stage, to avoid the loss of any sample which are received by the ports from the data acquisition system.

The PPI (Programmable Peripheral Interface) IC 8255 is used in the circuit for Input/Output ports, which can be programmed in a variety of ways so as to suit a particular system configuration. Different operating mode of 8255 is Mode 0, Mode 1 and Mode 2. In the present system, PPI 8255 is used in Mode '0'. The 8255A PPI provides three 8 bit ports named A,B and C. The 24 lines provided, are divided into two groups: Group A and Group B. Lines in port A and four lines of port C, PC_4-PC_7 (called the upper portion

of port C), constitute Group A and those in port B and the lower four, PC_0 - PC_3, in port C constitute Group B. Each port can be programmed to be either . an input or an output port. Also, port A can be used as a bidirectional bus for input/output.

4.4.3 Power Supply System:

A +5V power supply is required for the microprocessor system and a total current of about 500 mA will be needed. Data acquisition system requires a +5V, -5V, +15V and -15V power supply and current requirement is approximately 400 mA.

4.5 LABORATORY TESTING

The software programmes developed in Chapter 3 for the proposed relaying schemes for transmission line protection are stored separately in different EPROM and each scheme is tested and relay has correctly tripped the line, the tripping of line is indicated by glowing of LED.

In steady state, the interrupt 7.5 is always kept low as processor is primarily engaged for receiving samples and comparison thus of, as for the programmes. On occurence of disturbance on the system, the processor inters into a fault routine, to avoid to lose any sample during the period of computation, the interrupt 7.5 is enabled and processor

is interrupted by the EOC status of A/D converter at a frequency approximately equal to the sampling frequency.

The dynamic testing of the relay to investigate the transient over-reach and accuracy/range curves, could not be performed because of limited facilities available.

The operating specification of the relay is as

Voltage signal (from PT's)	:	+5V to -5V AC maximum
Current signal (from CT's)	:	+5V to -5V AC maximum
Supply requirements	:	+5V DC +15V DC -15V DC - 5V DC

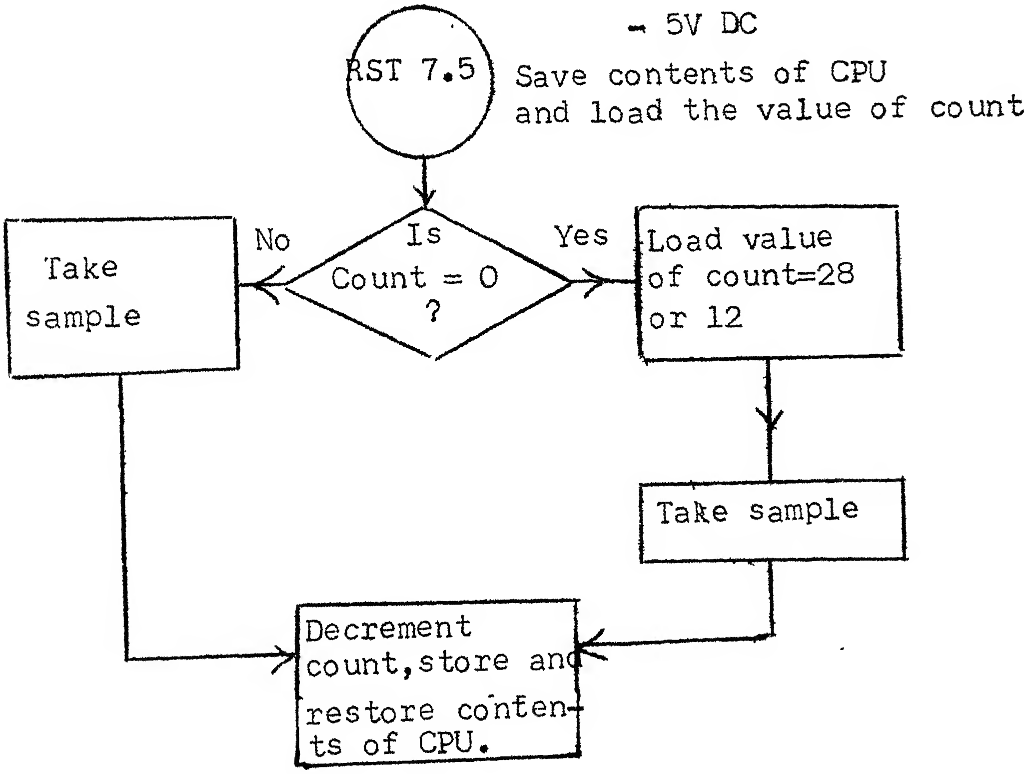


Fig. 4.5: Flow Chart 7.5 Interrupt Service Routine

CHAPTER 5

CONCLUSION

5.1 GENERAL

EHV and UHV transmission system needs a reliable, fast, efficient and low cost protection schemes, in order to transmit power reliably. Protection schemes using digital computers is a step ahead in this direction, as it is capable of realising complex threshold characteristics with lesser complexity and is of self checking nature. Accordingly, the primary objective of this thesis has been the design and development of microprocessor based protective relaying scheme. In the following sections, a brief account of the work carried out in this thesis, and also the scope for further work, are presented.

5.2 REVIEW OF THE WORK CARRIED OUT IN THIS THESIS

The protection schemes proposed in this thesis, are based upon the following two approaches:

a) Predictive calculation of peak fault current and voltage from a small number of sample values.

b) Fundamental component method taking samples for one-half power cycle.

In the proposed relaying scheme I, the software for realising three zone restricted Mho's relay characteristics has been developed which has been tested on a sample power system (see appendix D). The total operating time of relay from the instant the fault occurs is 4.94 ms for zone I,15.18ms for zone II and 25.44 ms for zone III. That is, the fault in zone I is cleared in less than a quarter cycle (5 ms).

In the proposed relaying scheme II, the software for realising three zone quadilateral characteristics has been developed and tested on a sample power system network (see Appendix D). The total operating time from the instant the fault occurs is 16.23 ms for zone I, 21.62 ms for zone II and 26.85 ms for zone III. That is, a fault in zone I is cleared in approximately one power cycle.

For the hardware realization of the above schemes, the relay based on microprocessor 8085 has been fabricated and tested. The relays comprises mainly, synchronising circuit; data acquisition system having sample/hold and analogue to digital converters; micro-computer using 8085A microprocessor. Provision exists for adding more memory and input/output ports if the situation demands. Visual display of the calculated fault impedance, distance to the fault point and type of fault can be obtained by interfacing TTY to the relay.

Any type of threshold characteristics such as that of plane impedance, direction relay, conical, hyperbola and over current relay can be obtained by developing the appropriate software.

5.3 SCOPE FOR FUTURE WORK

The proposed schemes, in single phase application, can be used for line to ground fault and in a three phase system, it can be used either for line to ground fault or phase to phase faults. However, the proposed relaying scheme can be extended for the discrimination of all the types of faults in three phase or multiphase system by using multiplexer and Direct Memory Access (DMA).

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APPENDIX A

NUMERICAL INTEGRATION

The general problem of numerical integration may be stated as follows. Given a set of data points $(x_o y_o)$, $(x_1 y_1), \ldots (x_n y_n)$ of a function $y = f(x)$ where $f(x)$ is not known explicitly, it is required to compute the values of definite integral,

$$I = \int_a^b y \, dx \qquad (A.1)$$

Let the interval [a,b] be sub-divided into N equal subinterval, such that, $a = x_o < x_1 < x_2 < \ldots < x_N = b$ clearly $x_n = x_o + Nh$ where h is the step size (i.e. length of interval). Hence the integration becomes

$$I = \int_{x_o}^{x_N} y dx \qquad (A.2)$$

Consider the figure A.1 . Let the samples are taken at a uniform interval. If the interval is small, then the area enclosed by two samples is approximately of

quadilateral form. Then the total area enclosed by the curve over a definite period x_o, x_1 is given by,

$$I_1 = \int_{x_o}^{x_1} y dx = h\,[y_o + y_1] \qquad (A.3)$$

Generalising it for the interval [a,b], we get,

$$I = \int_{x_o}^{x_1} y dx + \int_{x_1}^{x_2} y dx + \dots \int_{x_{N-1}}^{x_n} y dx \qquad (A.4)$$

$$= \frac{h}{2}\,[y_o + 2(y_1 + y_2 + \dots + y_{N-1}) + y_N\,]$$

which is known as Trapezoidal rule.

To evaluate V_d, V_q, I_d and I_q numerically, the above trapezoidal rule is applied. From equation(3.19)thus we get,

$$V_d = \frac{3\pi}{2T\omega} \int_{t_1}^{t_1+T\omega} V_{(t)} \cos \omega_2 (t - t_1 - \frac{T\omega}{2})\,dt \qquad (A.5)$$

Here $T\omega$ = time period = b-a = Nh

$$V_d = \frac{3\pi}{2xNh} \times \frac{h}{2} [V_{(t_1)} \cos \omega_2 (t_1 - t_1 - \frac{T\omega}{2}) + 2V_{(t_2)} \cos \omega_2$$

$$(t_2 - t_1 - \frac{T\omega}{2}) + 2V_{(t_3)} \cos\omega_2 (t_3 - t_1 - \frac{T\omega}{2}) + \dots$$

$$+ 2V_{(tN)} \cos\omega_2 (t_N - t_1 - \frac{T\omega}{2}) + V(t_{N+1}) \cos\omega_2 (t_{N+1} - t_1 - \frac{T\omega}{2})]$$

Since $T\omega = 2\pi/\omega_2$.

$$V_d = \frac{+3\pi}{4N}\left[V_{(t_1)}\cos(-\pi)+2V_{(t_2)}\cos\left(\frac{2\pi}{N}-\pi\right)+2V_{(t_3)}\cos\left(\frac{4\pi}{N}-\pi\right)+\ldots\right.$$

$$\left.+\ 2V_{(tN)}\cos\left(\frac{(N-1)\pi}{N}-\pi\right)+V_{(tN+1)}\cos(+\pi)\right] \qquad (A.6)$$

Similarly, for

$$V_q = \frac{-3\pi}{8N}\left[V_{(t_1)}\sin(-\pi)+2V_{(t_2)}\sin\left(\frac{2\pi}{N}-\pi\right)+2V_{(t_3)}\sin\left(\frac{4\pi}{N}-\pi\right)+\ldots\right.$$

$$\left.+2V_{(tN)}\sin\left(\frac{(n-1)2\pi}{N}-\pi\right)+V_{(tN+1)}\sin(\pi)\right] \qquad (A.7)$$

$$I_d = \frac{+3\pi}{4N}\left[I_{(t_1)}\cos(-\pi)+2I_{(t_2)}\cos\left(\frac{2\pi}{N}-\pi\right)+2I_{(t_3)}\cos\left(\frac{4\pi}{N}-\pi\right)+\ldots\right.$$

$$\left.+\ 2I_{(tN)}\cos\left(\frac{(n-1)2\pi}{N}-\pi\right)+I_{(tN+1)}\cos(\pi)\right] \qquad (A.8)$$

$$I_q = \frac{-3\pi}{8N}\left[I_{(t_1)}\sin(-\pi)+2I_{(t_2)}\sin\left(\frac{2\pi}{N}-\pi\right)+2I_{(t_3)}\sin\left(\frac{4\pi}{N}-\pi\right)+\ldots\right.$$

$$\left.+2I_{(tN)}\sin\left(\frac{(n-1)2\pi}{N}-\pi\right)+I_{(tN+1)}\sin(\pi)\right] \qquad (A.9)$$

Introducing $\frac{3\pi}{4N}$ = A constant and after simplification, we get,

$$V_d = A\left[V_{(t_1)}\cos\pi-2V_{(t_2)}\cos\frac{2\pi}{N}-2V_{(t_3)}\cos\frac{4\pi}{N}-\ldots\right.$$

$$\left.-2V_{(tN)}\cos\frac{(N-1)2\pi}{N}+V_{(tN+1)}\cos\pi\right] \qquad (A.10)$$

$$V_q = A\left[V_{(t_1)}\frac{\sin\pi}{2}+V_{(t_2)}\sin\frac{2\pi}{N}+V_{(t_3)}\sin\frac{4\pi}{N}+\ldots\right.$$

$$\left.+V_{(tN)}\sin\frac{(N-1)2\pi}{N}-V_{(tN+1)}\frac{\sin\pi}{2}\right] \qquad (A.11)$$

$$I_d = A[I_{(t_1)}\cos\pi - 2I_{(t_2)}\cos\frac{2\pi}{N} - 2I_{(t_3)}\cos\frac{4\pi}{N} - \cdots$$

$$- 2I_{tN} \cos\frac{(N-1)2\pi}{N} + I_{(tN+1)}\cos\pi] \quad (A.12)$$

$$I_q = A[I_{t_1} \frac{\sin\pi}{2} + I_{(t_2)}\sin\frac{2\pi}{N} + I_{(t_3)} \sin\frac{4\pi}{N} + \cdots$$

$$+ I_{(tN)}\sin\frac{(N-1)2\pi}{N} - I_{(tN+1)} \frac{\sin\pi}{2}] \quad (A.13)$$

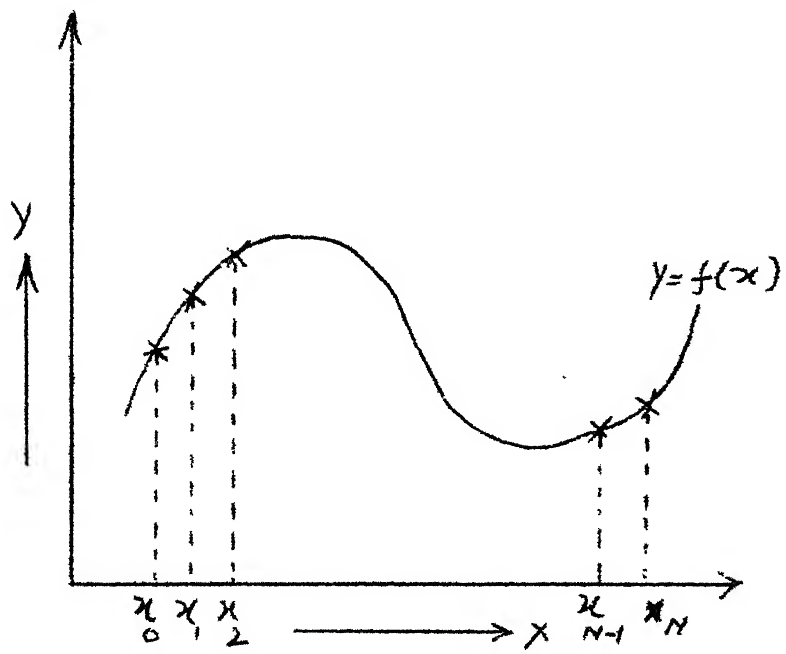

Fig. A-1

APPENDIX B

SELECTION OF SAMPLING RATE

Assume that the waveforms are sampled at an interval of Δt with actual sampling times being t_k , $t_{k+1}, \ldots$ and corresponding sampled value being v_k, $v_{k+1}, \ldots$ Take t_o as being half way between t_k and t_{k+1}. Then we get,

$$v_o = \frac{1}{2}(v_k + v_{k+1}) \tag{B.1}$$

$$v'_o \simeq \frac{\Delta v}{\Delta t} = \frac{1}{\Delta t}(v_{k+1} - v_k) \tag{B.2}$$

Since from (3.4) we know that,

$$V_{pk}^2 = (v)^2 + (\frac{v'}{\omega})^2 \tag{B.3}$$

So, this yields an estimate V_o of V at time t_o as

$$V_o{}^2 = v_o{}^2 + (\frac{\Delta v}{\omega \Delta \tau} \bigg|_{t=t_o})^2 \tag{B.4}$$

Put the value of v_o and $\Delta v/\Delta t$ from equations(B.1) and (B.2) into equation (B.4) we get,

$$V_o{}^2 = [\frac{1}{2}(v_k + v_{k+1}) \big|_{t=t_o}]^2 + [\frac{v_{k+1} - v_k}{\omega \Delta t} \big|_{t=t_o}]^2$$

$$= \frac{V_{pk}^2}{4}[\sin\omega t_o - \frac{1}{2}\omega\Delta t + \sin(\omega t_o + \frac{1}{2}\omega\Delta t]^2 + \frac{V_{pk}^2}{(\omega\Delta t)^2} \times$$

$$[\sin(\omega t_o + \frac{1}{2}\omega\Delta t) - \sin(\omega t_o - \frac{1}{2}\omega\Delta t]^2$$

Expanding the above and neglecting the high order term for sake of simplicity we get,

$$V_o = V_{pk} \left[1 - \frac{\omega^2(\Delta t)^2}{4} \sin^2\omega t_o + \ldots \right] \qquad (B.5)$$

For $\Delta t = 0.5$ ms, the equation (B.5), gives a maximum error in V_o on 50 Hz system of 0.15%, numerical analysis list the several ways of calculating the derivative [48]-[50]. In general, these methods are series expression of forward, backward or central differences. The actual formula for numerical differentation can be obtained by differentiating the interpolating polynomial, i.e. interpolation formula. Isaacon and Keeler [90] have shown that interpolation error are least near the centre of interval of interpolation which is equivalent of using interpolating formula developed using central difference. But it is advantageous, for real time implementation, to use backward difference for calculating the derivative using existing samples. These consideration led to the tentative selection of a sampling interval of 0.5 ms i.e. 40 samples per cycle.

APPENDIX C

DIFFERENTIATION FORMULAS

Using the standard notation ∇ , δ and μ for the operation of backward differencing, central differencing and averaging respectively, the basic central difference expression for derivative [49] is

$$hy'_k = (\mu\ \delta - \frac{1}{6}\ \mu\ \delta^3 + \frac{1}{30}\ \mu\ \delta^3 - \ldots)y_k) \qquad (C.1)$$

where $h = \Delta t$ and y stands for v and i respectively.

Using the first term only of the above result (eqn.C.1) we get,

$$hy'_k = \frac{1}{2}\ (y_{k+1} - y_{k-1}) \qquad (C.2)$$

And using also the second term of above result (eqn. C-1) we get,

$$hy'_k = -\ \frac{1}{12}\ (y_{k+2} + \frac{2}{3}\ y_{k-1} - \frac{2}{3}\ y_{k-1} + \frac{1}{12}\ y_{k-2}\ ) \qquad (C.3)$$

the backward differences expression for derivative [49] is,

$$hy'_k = (\nabla - \frac{1}{2}\ \nabla^2 - \ldots\ )y_k\ \ldots \qquad (C.4)$$

Using the first term only of result (eqn. C.4) we get,

$$hy'_k = y_k - y_{k-1} \qquad (C.5)$$

And using also the second term of the result (eqn. C.4) we get,

$$hy'_k = \frac{1}{2}(y_k - y_{k-2}) \qquad (C.6)$$

From the above, it is clear, that, the expression at (C.2), (C.3) require sample value at times later than t_k, whereas expression (C.5) and (C.6) do not. Thus any of central difference and backward difference can be considered as possible ways of calculating the derivative.

APPENDIX D

TRANSMISSION LINE DATA [26]

Base	= 230 KV, 1000 MVA
Length of line	= 300 miles
Line Parameters:	
Positive sequence reactance	= $j0.123 \times 10^{-2}$ p.u.
Positive sequence resistance	= 0.223×10^{-3} p.u.
Zero sequence resistance	= 1.226×10^{-3} p.u.
Zero sequence reactance	= $j0.32 \times 10^{-3}$ p.u.
Positive sequence capacitive reactance	= $-j420$ p.u.
Zero sequence capacitive reactance	= $-j714$ p.u.
Source impedance Z_s	= $0.033+j0.315$

```
                      ;-----------------------------------------------------
                      ; REAL TIME MICROPROCESSOR BASED PROGRAMME FOR
                      ;THREE ZONE RESTRICTED MHO RELAY
                      ;-----------------------------------------------------
                      ;ASSIGNMENT MEMORY LOCATION FOR VARIBALES
4000                  DATUM EQU 4000H    ;SAMPLES OF VOLTAGE & CURRENT
0490                  COSTA EQU 0490H    ;COS LOOK UP TABLE
6000                  PORTV EQU 6000H   ;PORT 1 FOR VOLTAGE SAMPLES
6001                  PORTI EQU 6001H     ;PORT 2 FOR CURRENT SAMPLES
0410                  TANGT EQU 0410H       ;TAN LOOK UP TABLE
4056                  AMLA  EQU 4056H
4057                  VANGL EQU 4057H       ;STORING THE ANGLE OF VOLTAGE
4058                  IANGL EQU 4058H       ;STORING THE ANGLE OF CURRENT
4059                  FIRST EQU 4059H     ;STORING VALUE OF VPEAK SQUARE
405C                  SECND EQU 405CH   ;STORING VALUE OF IPEAK SQUARE
405E                  THIRD EQU 405EH    ;USED AS TEMPORARY STORAGE
4060                  FORTH EQU 4060H
4062                  FIFTH EQU 4062H
4064                  INTIC EQU 4064H
4065                  BASE EQU 4065H     ;USED AS TEMPORARY STORAGE
4066                  VBASE EQU 4066H
6002                  PORTC EQU 6002H    ;CONTROL PORT OF PPI
6003                  CWPPI EQU 6003H    ; CONTROL WORD OF PPI
4067                  VDERI EQU 4067H    ; STORING VOLTAGE DERIVATIVE
                                ; CURRENT,CURRENT DERIVATIVE
0000                  ORG 0000H
0000    31FF42        LXI SP,42FFH
                      ;++++++++++++++++++++++++++++++++++++++++++++++++++++
                      ;INTIALISATION OF INPUTPORT/OUTPUTPORTS COUNTERS
                      ;++++++++++++++++++++++++++++++++++++++++++++++++++++
0003    3E93           MVI A,93H      ; PORTA=INPUT=PORTB
                                 ; PORTC LOWER=INPUT
                                 ; PORTC UPPER=OUTPUT
0005    320360         STA CWPPT
0008    3E02           MVI A,02H
000A    325640         STA AMLA
000D    3E00           MVI A,00H
000F    320260         STA PORTC
0012    210040         LXI H,DATUM
0015    0E28           MVI C,28H
0017    3A0260        FLAKE: LDA PORTC
001A    1F             RAR
001B    DA2100         JC LAMB
001E    C31700         JMP FLAKE
0021    3A0060        LAMB : LDA PORTV
0024    CD6503         CALL DELHI
0027    77             MOV M,A
0028    23             INX H
0029    3A0160         LDA PORTI
002C    CD6503         CALL DELHI
002F    77             MOV M,A
0030    0D             DCR C
0031    CA8200         JZ FRESH
0034    C31700         JMP FLAKE
0037    00             NOP
0038    00             NOP
0039    00             NOP
003A    00             NOP
003B    00             NOP
003C    F5            RST75 :  PUSH PSW
003D    E5             PUSH H
003E    D5             PUSH D
003F    3A6440         LDA INTIC
0042    FE00           CPI 0H
0044    CA5C00         JZ HOLDG
0047    57             MOV D,A
0048    3E28           MVI A,28H
004A    92             SUB D
004B    210040         LXI H,DATUM
004E    5F             MOV E,A
004F    1600           MVI D,0H
0051    19             DAD D
0052    3A0060         LDA PORTV
0055    CD6503         CALL DELHI
```

```
0058    77          MOV M,A
0059    C36B00      JMP VENKT
005C    3E28      HOLDG: MVI A,28H
005E    326440      STA INTIC
0061    210040      LXI H,DATUM
0064    3A0060      LDA PORTV
0067    CD6503      CALL DELHI
006A    77          MOV M,A
006B    D1        VENKT: POP D
006C    E1          POP H
006D    F1          POP PSW
006E    C9          RET
006F    3A6440    ORGIN: LDA INTIC
0072    4F          MOV C,A
0073    3E28        MVI A,28H
0075    91          SUB C
0076    210040      LXI H,DATUM
0079    5F          MOV E,A
007A    1600        MVI D,0H
007C    19          DAD D
007D    1E00        MVI E,0H
007F    C3A100      JMP SAMPL
                  ;-----------------------------------------------
                  ;COLLECTION OF SAMPLES OF VOLTAGE AND CURRENT AND
                  ;CYCLE BY CYCLE COMPARISON OF VOLTAGE SAMPLES AND
                  ;REPLACING THE PREVIOUS BY LATEST SAMPLES OF VS C
                  ;-----------------------------------------------
0082    1E00      FRESH: MVI E,00H
0084    0E28        MVI C,28H
0086    210040      LXI H,DATUM
0089    C3A100      JMP SAMPL
008C    23        INCR : INX H
008D    0D          DCR C
008E    CA8200      JZ FRESH
0091    C3A100      JMP SAMPL
0094    3E00      DECRE:  MVI A,0H
0096    BB          CMP E
0097    CA9B00      JZ GHOST
009A    1D          DCR E
009B    AF        GHOST:  XRA A
009C    23          INX H
009D    0D          DCR C
009E    CA8200      JZ FRESH
00A1    46        SAMPL:  MOV B,M
00A2    3A0260    BOTHM: LDA PORIC
00A5    1F          RAR
00A6    DAAC00      JC DOWER
00A9    C3A200      JMP BOTHM
00AC    3A0060    DOWER: LDA PORIV
00AF    CD6503      CALL DELHI
00B2    77          MOV M,A
00B3    23          INX H
00B4    3A0160      LDA PORTT
00B7    CD6503      CALL DELHI
00BA    77          MOV M,A
00BB    2B          DCX H
00BC    78          MOV A,B
00BD    56          MOV D,M
00BE    BA          CMP D
00BF    DAC500      JC LOCK
00C2    C3C800      JMP KEY
00C5    47        LOCK :  MOV B,A
00C6    7A          MOV A,D
00C7    50          MOV D,B
00C8    92        KEY  :  SUB D
00C9    1605        MVI D,05H
00CB    BA          CMP D
00CC    DAD200      JC MAXY
00CF    C3D700      JMP SOLO
00D2    AF        MAXY :  XRA A
00D3    23          INX H
00D4    C39400      JMP DECRE
00D7    1C        SOLO :  INR E
00D8    3E02        MVI A,02H
```

```
0DA   BB       CMP E
00DB  CAE200   JZ ZCAL
00DE  23       INX H
00DF  C3B200   JMP INCR
               ;-----------------------------------------------
               ;CALCULATION OF IMPEDANCE
               ;-----------------------------------------------
00E2  0D       ZCAL : DCR C
00E3  79       MOV A,C
00E4  326140   STA INTIC
00E7  CD4403   CALL DERIV ;CALCULATE DERIVATIVE OF VOLTAGE
00EA  116740   LXI D,VDERT
00ED  3A6540   LDA BASE
00F0  325540   STA VBASE
00F3  EB       XCHG
00F4  78       MOV A,B
00F5  77       MOV M,A
00F6  23       INX H
00F7  79       MOV A,C
00F8  77       MOV M,A
00F9  EB       XCHG
00FA  23       INX H
00FB  23       INX H
00FC  23       INX H
00FD  CD4403   CALL DERIV  ;CALCULATE CURRENT DERIVATIVE
0100  216740   LXI H,VDERT
0103  23       INX H
0104  23       INX H
0105  78       MOV A,B
0106  77       MOV M,A
0107  23       INX H
0108  79       MOV A,C
0109  77       MOV M,A
               ;++++++++++++++++++++++++++++++++++++++++++++++++
               ; CALCULATE  VALUE OF (VPEAK) AND (IPEAK) FROM
               ;LATEST VALUE OF SAMPLES AND DERIVATIVES
               ;++++++++++++++++++++++++++++++++++++++++++++++++
010A  2B       DCX H
010B  2B       DCX H
010C  2B       DCX H
010D  AF       XRA A
010E  7E       LIME :MOV A,M
010F  47       MOV B,A
0110  E5       PUSH H
0111  CD7703   CALL MULTI
0114  225E40   SHLD THIRD
0117  E1       POP H
0118  23       INX H
0119  7E       MOV A,M
011A  0610     MVI B,10H
011C  E5       PUSH H
011D  CD7703   CALL MULTI
0120  4D       MOV C,L
0121  44       MOV B,H
0122  1600     MVI D,00H
0124  1E05     MVI E,05H
0126  7C       MOV A,H
0127  BB       CMP E
0128  DA3301   JC PHULN
012B  CD8703   CALL VISON ;REG B-C CONTAINS QUOTIENT
012E  79       MOV A,C
012F  41       MOV B,C
0130  C33901   JMP SUNDR
0133  43       PHULN: MOV B,E
0134  CD9503   CALL DIVIS
0137  7A       MOV A,D
0138  42       MOV B,D
0139  CD7703   SUNDR: CALL MULTI
013C  EB       XCHG
013D  2A5E40   LHLD THIRD
0140  19       DAD D
0141  3A5640   LDA [illegible]LA
0144  3D       DCR A
0145  C24801   JNZ TIMES
```

```
0148   C35C01        JMP FUNES
014B   325540   FINES: STA AMLA
014E   7D            MOV A,L
014F   44            MOV B,H
0150   215940        LXI H,FIRST
0153   77            MOV M,A
0154   23            INX H
0155   78            MOV A,B
0156   77            MOV M,A
0157   E1            POP H
0158   23            INX H
0159   C30E01        JMP LINE
015C   3C       FUNES: INR A
015D   3C            INR A
015E   325540        STA AMLA
0161   7D            MOV A,L
0162   44            MOV B,H
0163   215C40        LXI H,SECND
0166   77            MOV M,A
0167   23            INX H
0168   78            MOV A,B
0169   77            MOV M,A
016A   E1            POP H
016B   2B            DCX H
016C   2B            DCX H
016D   2B            DCX H
                ;-----------------------------------------------------
                ; CALCULATE RAITO  .  R= /( / ) =32 /   OBTAINED AS
                ;0.32 / *100=32 /  (              ) TO GET ANGLE
                ;CALCULATE RATIO OF VOLTAGE /VOLTAGE DERIVATIVE/
                ;AND FOR CURRENT DIVIDED BY CURRENT DERIVATIVE/
                ;-----------------------------------------------------
016E   7E       MATH :  MOV A,M  ;
016F   0620          MVI B,20H
0171   E5            PUSH H
0172   CD7703        CALL MULTI  ;
0175   4D            MOV C,L
0176   44            MOV B,H
0177   E1            POP H
0178   23            INX H
0179   5E            MOV E,M
017A   1600          MVI D,00H
017C   E5            PUSH H
017D   CD8703        CALL VISON   ;REG B-C CONTAINS QUOTIENT
0180   59            MOV E,C
0181   50            MOV D,B
0182   E1                 POP H
0183   0E00          MVI C,00H
0185   7A            MOV A,D
0186   E607          ANI 00000111B
0188   1F            RAR
0189   DA9701        JC NAMAK
018C   1F            RAR
018D   DAA101        JC HARAM
0190   1F       KISAN :  RAR
0191   DAAB01        JC ARMAN
0194   C3AF01        JMP KUTAB
0197   0C       NAMAK :  INR C
0198   3F            CMC
0199   1F            RAR
019A   DAA101        JC HARAM
019D   3F            CMC
019E   C39001        JMP KISAN
01A1   0C       HARAM :  INR C
01A2   0C            INR C
01A3   3F            CMC
01A4   1F            RAR
01A5   DAAB01        JC ARMAN
01A8   C3AF01        JMP KUTAB
01AB   0C       ARMAN :  INR C
01AC   0C            INR C
01AD   0C            INR C
01AE   0C            INR C
01AF   3E00     KUTAB :  MVI A,00H
```

```
01B1    B9        CMP C
01B2    CADC01    JZ KARZ
01B5    3E01      MVI A,01H
01B7    B9        CMP C
01B8    CAE501    JZ KARAM
01BB    3E02      MVI A,02H
01BD    B9        CMP C
01BE    CAF201    JZ GANDI
01C1    3E03      MVI A,03H
01C3    B9        CMP C
01C4    CA0002    JZ MANDI
01C7    3E04      MVI A,04H
01C9    B9        CMP C
01CA    CA0F02    JZ SUBZI
01CD    3E05      MVI A, 05H
01CF    B9        CMP C
01D0    CA1402    JZ JAVAK
01D3    3E06      MVI A,06H
01D5    B9        CMP C
01D6    CA1902    JZ PURT
01D9    C31902    JMP PURI
01DC    AF        KARZ : XRA A
01DD    7B        MOV A,E
01DE    E6FC      ANI 11111100B
01E0    0F        RRC
01E1    0F        RRC
01E2    C31E02    JMP GUDDI
01E5    AF        KARAM: XRA A
01E6    7B        MOV A,E
01E7    E6F0      ANI 11110000B
01E9    0F        RRC
01EA    0F        RRC
01EB    0F        RRC
01EC    0F        RRC
01ED    C63F      ADI 03FH
01EF    C31E02    JMP GUDDI
01F2    AF        GANDI : XRA A
01F3    7B        MOV A,E
01F4    E6E0      ANI 11100000B
01F6    0F        RRC
01F7    0F        RRC
01F8    0F        RRC
01F9    0F        RRC
01FA    0F        RRC
01FB    C64E      ADI 04EH
01FD    C31E02    JMP GUDDI
0200    AF        MANDI: XRA A
0201    7B        MOV A,E
0202    E6C0      ANI 11000000B
0204    0F        RRC
0205    0F        RRC
0206    0F        RRC
0207    0F        RRC
0208    0F        RRC
0209    0F        RRC
020A    C655      ADI 55H
020C    C31E02    JMP GUDDI
020F    3E58      SUBZI: MVI A,58H
0211    C31E02    JMP GUDDI
0214    3E58      JANAK : MVI A,058H
0216    C31E02    JMP GUDDI
0219    3E5E      PURI: MVI A,05EH
021B    C31E02    JMP GUDDI
021E    5F        GUDDI: MOV E,A
021F    1600      MVI D,00H
0221    E5        PUSH H
0222    211004    LXI H,TANGT
0225    19        DAD D
0226    7E        MOV A,M
0227    47        MOV B,A
0228    E1        POP H
0229    3A5640    LDA AMDA
022C    3D        DCR A
022D    C23302    JNZ PATIL
```

```
0230   C34402   JMP SOHAN
0233   325540   PATIL: STA AMGA
0236   3A6540   LDA VBASE
0239   FE00     CPI 00H
023B   CA4202   JZ PANAM
023E   90       SUB B
023F   C34302   JMP SOANG
0242   80       PANAM: ADD B
0243   325740   SOANG: STA VANGL
0246   23       INX H
0247   C36E01   JMP MATH
024A   3A6540   SOHAN: LDA BASE
024D   FE00     CPI 00H
024F   CA5602   JZ CANAL
0252   90       SUB B
0253   C35702   JMP RIVER
0256   80       CANAL: ADD B
0257   325840   RIVER: STA TANGL
                ;-----------------------------------------------
                ; CALCULATE IMPEDANCE , COMPARE WITH  SET VALUE
                ;-----------------------------------------------
025A   2A5C40   LHLD SECND
025D   EB       XCHG
025E   2A5940   LHLD FIRST
0261   0600     MVI B,0H
0263   CDFC03   CALL LTQUD
                ;REG B = QUOTIENT ,H-L= REMAINDER
                ;REG D-E CONTAINS SECND(DIVISOR)
0266   AF       XRA A
0267   78       MOV A,B
0268   07       RLC
0269   07       RLC
026A   07       RLC
026B   80       ADD B
026C   80       ADD B
                ;REG A CONTAINS 10*QUOTIENT
                ;REGPAIR H-L CONTAINS REMAINDER
026D   4D       MOV C,L
026E   44       MOV B,H
026F   29       DAD H
0270   29       DAD H
0271   29       DAD H
0272   09       DAD B
0273   09       DAD B
0274   47       MOV B,A
                ;  CHECK WHETHER  CONTENTS OF  REG  H-L
                ;IS GREATER THAN CONTENTS OF REG PAIR D-E
                ;CONTENTS OF H-L =10*REMAINDER
0275   7D       MOV A,L
0276   BB       CMP E
0277   DA8202   JC MSUB
027A   7C       MOV A,H
027B   BA       CMP D
027C   DA8C02   JC MONA
027F   C38902   JMP APPAR
0282   AF       MSUB : XRA A
0283   7C       MOV A,H
0284   3D       DCR A
0285   BA       CMP D
0286   DA8C02   JC MONA
0289   CDFC03   APPAR: CALL LTQUD
                ;-----------------------------------------------
                ; CALCULATE  ANGLE OF IMPEDANCE AND  CHECK WHETHER
                ; IT LIES WITHIN 0+30 DEGRES
                ;-----------------------------------------------
028C   215740   MONA: LXI H, VANGL
028F   58       MOV E,B ;REG E CONTAINS VALUE OF IMPEDANCE
0290   7E       MOV A,M
0291   57       MOV D,A
0292   23       INX H
0293   4E       MOV C,M
0294   B9       CMP C
0295   DA9C02   JC POWER
0298   91       SUB C
```

```
0299   C3A202    JMP IMPAN
029C   79        POWER:  MOV A,C
029D   92          SUB D
029E   47          MOV B,A
029F   3EB4        MVI A,0B4H
02A1   90          SUB B
02A2   065A      IMPAN:  MVI B,05AH
02A4   B8          CMP B
02A5   DAAB02      JC STORE
02A8   C36F00      JMP ORGIN
                   ; REG A CONTAINS ANGLE OF IMPEDANCE
                   ;REG E CONTAINS CALCULATED IMPEDANCE
02AB   57        STORE:  MOV D,A
02AC   0641        MVI B,41H
02AE   B8          CMP B
02AF   DAB502      JC SALT
02B2   90          SUB B
02B3   C3BB02      JMP SUGAR
02B6   78        SALT :  MOV A,B
02B7   92          SUB D
02B8   C3BB02      JMP SUGAR
02BB   FE00      SUGAR:  CPI 00H
02BD   CAFD02      JZ CAMPA
                   ; TO CALCULATE ZR**(COS**&)>ZC**
02C0   219004    COALA:  LXI H,COSTA
02C3   42          MOV B,D
02C4   43          MOV C,E
02C5   1600        MVI D,0H
02C7   5F          MOV E,A
02C8   83          ADD E
02C9   5F          MOV E,A
02CA   19          DAD D
02CB   7E          MOV A,M
02CC   5F          MOV E,A
02CD   23          INX H
02CE   7E          MOV A,M
02CF   57          MOV D,A
02D0   EB          XCHG
02D1   226040      SHLD FORTH
02D4   29          DAD H
02D5   29          DAD H
02D6   225E40      SHLD THIRD  ;
02D9   AF          XRA A
02DA   79          MOV A,C
02DB   07          RLC
02DC   07          RLC
02DD   81          ADD C
02DE   06C8        MVI B,0C8H
02E0   CD7703      CALL MULTI
02E3   EB          XCHG
02E4   2A5E40      LHLD THIRD
02E7   7D          MOV A,L
02E8   BB          CMP E
02E9   DAF402      JC LIMCA
02EC   7C          MOV A,H
02ED   BA          CMP D
02EE   DA0503      JC ZONE2
02F1   C31E04       JMP TRIP1
02F4   7C        LIMCA:  MOV A,H
02F5   3D          DCR A
02F6   BA          CMP D
02F7   DA0503      JC ZONE2
02FA   C31E04      JMP TRIP1
02FD   7B        CAMPA:  MOV A,E
02FE   FE28        CPI 28H
0300   DA1E04      JC TRIP1
0303   C30503      JMP ZONE2
                 ;------------------------------------------------------------
                 ;TO CHECK FOR ZONE2 OPERATION
                 ;------------------------------------------------------------
                 ;REG PAIR H-L CONTAIN 4C05(A)
0306   29        ZONE2:  DAD H
0307   226240      SHLD FIFTH
030A   D5          PUSH D
```

```
0308  EB      XCHG
030C  2A5040  LHLD FORTH
030F  19      DAD D
0310  D1      POP D
              ;REG PAIR H-L CONTAIN BCDS(S)
0311  7D      MOV A,L
0312  BB      CMP E
0313  DA1E03  JC SCROL
0316  7C      MOV A,H
0317  BA      CMP D
0318  DA2703  JC ZONE3
031B  C32604  JMP TRIP2
031E  7C     SCROL: MOV A,H
031F  3D      DCR A
0320  BA      CMP D
0321  DA2703  JC ZONE3
0324  C32604  JMP TRIP2
             ;------------------------------------------------
             ; TO CHECK FOR ZONE3 OPERATION
             ;------------------------------------------------
0327  2A6240 ZONE3: LHLD FIFTH
032A  29      DAD H
032B  7D      MOV A,L
032C  BB      CMP E
032D  DA3803  JC SHIFT
0330  7C      MOV A,H
0331  BA      CMP D
0332  DA4103  JC PEPSI
0335  C32E04  JMP TRIP3
0338  7C     SHIFT: MOV A,H
0339  3D      DCR A
033A  BA      CMP D
033B  DA4103  JC PEPSI
033E  C32E04  JMP TRIP3
0341  C36F00 PEPSI: JMP ORGIN
             ;------------------------------------------------
             ;          SUBROUTINES
             ;------------------------------------------------
0344  46     DERTV : MOV B,M
0345  50      MOV D,B
0346  2B      DCX H
0347  2B      DCX H
0348  7E      MOV A,M
0349  B8      CMP B
034A  DA5803  JC RAJNI
034D  48      MOV C,B
034E  47      MOV B,A
034F  50      MOV D,B
0350  3E80          MVI A,0BOH
0352  325540  STA BASE
0355  C35E03  JMP RANY
0358  4F     RAJNI: MOV C,A
0359  3E00    MVI A,00H
035B  325540  STA BASE
035E  78     RANY : MOV A,B
035F  91      SUB C
0360  47      MOV B,A
0361  80      ADD B
             ; REG A CONTAINS DERIVATIVE
0362  4F      MOV C,A
0363  42      MOV B,D
0364  C9      RET
             ;++++++++++++++++++++++++++++++++++++++++++++++++
             ;TO CONVERT THE OFFSET BINARY NUMBER
             ;++++++++++++++++++++++++++++++++++++++++++++++++
0365  37     DELHI: STC
0366  3F      CMC
0367  17      RAL
0368  DA7303  JC TRECI
036B  1F      RAR
036C  F680    ORI 10000000B
036E  2F      CMA
036F  3C      INR A
0370  C37603        JMP KORAN
```

```
0373  1F      TRCC1: RAR
0374  E67F     ANI 01111111B
0376  C9      KORAR: RET
              ;++++++++++++++++++++++++++++++++++++++++++++++++
              ; MULTIPLICATION SUBROUTINE
              ;MULTIPLIER IN REG A AND MULTIPLICANT IN REG B
              ;RESULT IN REG PAIR H AND L
              ;++++++++++++++++++++++++++++++++++++++++++
0377  210000  MULTI : LXI H,0000H
037A  1608     MVI D,08H
037C  48       MOV C,B
037D  44       MOV B,H
              ;MULTIPLIER IN REG A AND MULTIPLICANT IN B-
037E  0F      CASIO : RRC
037F  D28303   JNC SIGN
0382  09       DAD B
0383  15      SIGN : DCR D
0384  CA9403   JZ ASHTR
0387  5F       MOV E,A
0388  79       MOV A,C
0389  37       STC
038A  3F       CMC
038B  17       RAL
038C  4F       MOV C,A
038D  78       MOV A,B
038E  17       RAL
038F  47       MOV B,A
0390  7B       MOV A,E
0391  C37E03   JMP CASIO
0394  C9      ASHTR: RET
              ;++++++++++++++++++++++++++++++++++++++++++++++++
              ; DIVISON SUBROUTINE REG D QUOTIENT REG B DIVISOR
              ;++++++++++++++++++++++++++++++++++++++++++++++++
0395  78      DIVIS: MOV A,B
0396  1600     MVI D,00H
0398  1E00     MVI E,00H
039A  7B      DUSTL : MOV A,E
039B  FE08     CPI 08H
039D  CAAF03   JZ BLADE
03A0  29       DAD H
03A1  1C       INR E
03A2  7A       MOV A,D
03A3  07       RLC
03A4  57       MOV D,A
03A5  7C       MOV A,H
03A6  90       SUB B
03A7  DAAC03   JC SOAP
03AA  14       INR D
03AB  67       MOV H,A
03AC  C39A03  SOAP : JMP DUSTL
03AF  7C      BLADE : MOV A,H
03B0  07       RLC
03B1  B8       CMP B
03B2  DAB603   JC WATER
03B5  14       INR D
03B6  C9      WATER : RET
              ;================================================
              ;16 BITS DIVISON SUBROUTINE REG B-C PAIR INTIALLY
              ;CONTAINS DIVEDEND REG  D-E= DIVISOR IN END
              ;REG B-C=QUOTIENT, REG H-L CONTAINS REMAINDER
              ;================================================
03B7  210000  VISON: LXI H,0000H
03BA  D5       PUSH D
03BB  7A       MOV A,D
03BC  2F       CMA
03BD  57       MOV D,A
03BE  7B       MOV A,E
03BF  2F       CMA
03C0  5F       MOV E,A
03C1  13       INX D
03C2  3E11     MVI A,17D
03C4  E5      MINTD: PUSH H
03C5  19       DAD D
03C6  D2CA03   JNC CHINT
```

```
03C9   E3              XTHL
03CA   E1        CHINI: POP H
03CB   F5              PUSH PSW
03CC   79              MOV A,C
03CD   17              RAL
03CE   4F              MOV C,A
03CF   78              MOV A,B
03D0   17              RAL
03D1   47              MOV B,A
03D2   7D              MOV A,L
03D3   17              RAL
03D4   6F              MOV L,A
03D5   7C              MOV A,H
03D6   17              RAL
03D7   67              MOV H,A
03D8   F1              POP PSW
03D9   3D              DCR A
03DA   C2C403          JNZ MINTO
                 ;SHIFT REMAINDER RIGHT & RETURN IN H-L
03DD   B7              ORA A
03DE   7C              MOV A,H
03DF   1F              RAR
03E0   67              MOV H,A
03E1   7D              MOV A,L
03E2   1F              RAR
03E3   6F              MOV L,A
03E4   D1              POP D
03E5   29              DAD H
03E6   7D              MOV A,L
03E7   BB              CMP E
03E8   DAF303          JC LSUB
03EB   7C              MOV A,H
03EC   BA              CMP D
03ED   DAFB03          JC IDNA
03F0   C3FA03          JMP SIPPU
03F3   AF        LSUB : XRA A
03F4   7C              MOV A,H
03F5   3D              DCR A
03F6   BA              CMP D
03F7   DAFB03          JC IDNA
03FA   03        SIPPU: INX B
03FB   C9        IDNA : RET   ;REG B-C=QUOTIENT
                 ;++++++++++++++++++++++++++++++++++++++++
                 ;TO FIND IMPEDANCE FROM VPEAK AND IPEAK
                 ;++++++++++++++++++++++++++++++++++++++++++++++
03FC   AF        LIQUD: XRA A
03FD   7D              MOV A,L
03FE   9B              SBB E
03FF   6F              MOV L,A
0400   7C              MOV A,H
0401   9A              SBB D
0402   67              MOV H,A
0403   04              INR B
0404   AF              XRA A
0405   7D              MOV A,L
0406   BB              CMP E
0407   DA1204          JC DONE
040A   7C              MOV A,H
040B   BA              CMP D
040C   DA1C04          JC ERASE
040F   C3FC03          JMP LIQUD
0412   AF        DONE : XRA A
0413   7C              MOV A,H
0414   3D              DCR A
0415   BA              CMP D
0416   DA1C04          JC ERASE
0419   C3FC03          JMP LIQUD
041C   AF        ERASE : XRA A
041D   C9              RET   ;AS RESULT REG H-L CONTAINS REMAINDER
                 ;++++++++++++++++++++++++++++++++++++++++++++++
                 ;          TRIP SIGNAL
                 ;++++++++++++++++++++++++++++++++++++++++++++++
041E   3E80      TRIP1: MVI A,80H
0420   320260          STA PORTC
```

```
0423    C31E04    JMP TRIP1
0425    3E20      TRIP2: MVI A,20H
0428    320260     STA PORTC
042B    C32504     JMP TRIP2
042E    3E40      TRIP3: MVI A,40H
0430    320260     STA PORTC
0433    C32E04     JMP TRIP3
0436    76          HLT
0410                ORG TANGT
0410    02050709  DB 2H,5H,7H,9H,0BH,0EH,10H,12H,14H,16H,18H
0414    0B0E1012
0418    141618
041B    1A1C1D1F  DB 1AH,1CH,1DH,1FH,21H,22H,24H,25H,27H
041F    21222425
0423    27
0424    28292B2C  DB 28H,29H,2BH,2CH,2DH,2EH,2FH,30H,31H,32H
0428    2D2E2F30
042C    3132
042E    33343536  DB 33H,34H,35H,36H,36H,37H,38H,39H,39H,3AH
0432    36373839
0436    393A
0438    3B3B3C3C  DB 3BH,3BH,3CH,3CH,3DH,3EH,3EH,3EH,3FH,3FH
043C    3D3E3E3E
0440    3F3F
0442    40404141  DB 40H,40H,41H,41H,41H,42H,42H,43H,43H,43H
0446    41424243
044A    4343
044C    44444445  DB 44H,44H,44H,45H,46H,47H,48H,49H,4AH,4BH
0450    46474849
0454    4A4B
0456    4B4C4C4C  DB 4BH,4CH,4CH,4CH,4DH,4EH,4EH,4EH,4FH,50H
045A    4D4E4E4E
045E    4F50
0460    50515152  DB 50H,51H,51H,52H,52H,52H,53H,54H,55H,55H
0464    52525354
0468    5555
046A    56575757  DB 56H,57H,57H,57H,58H,58H,58H
046E    585858
0490              ORG COSTA
0490    10270C27  DB 10H,27H,0CH,27H,01H,27H,0DFH,26H,0C4H,27H
0494    0127DF26
0498    C427
049A    A2267B26  DB 0A2H,26H,7BH,26H,4EH,26H,1BH,26H,0E2H,25H
049E    4E261B26
04A2    E225
04A4    A3255F25  DB 0A3H,25H,5FH,25H,16H,25H,0C6H,24H,72H,24H
04A8    1625C624
04AC    7224
04AE    1824B923  DB 18H,24H,0B9H,23H,55H,23H,0ECH,22H,7EH,22H
04B2    5523EC22
04B6    7E22
04B8    08229421  DB 08H,22H,94H,21H,19H,21H,99H,20H,16H,20H
04BC    19219920
04C0    1620
04C2    8E1F031F  DB 8EH,1FH,03H,1FH,74H,1EH,0E1H,1DH,4BH,1DH
04C6    741EE11D
04CA    4B1D
04CC    B31C181C  DB 0B3H,1CH,18H,1CH,7AH,1BH,0D9H,1AH,36H,1AH
04D0    7A1BD91A
04D4    361A
04D6    9119EA18  DB 91H,19H,0EAH,18H,0E1H,18H,97H,17H,0ECH,16H
04DA    E1189717
04DE    EC16
04E0    3F169315  DB 3FH,16H,93H,15H,0E4H,14H,36H,14H,87H,13H
04E4    E4143614
04E8    8713
04EA    D9122B12  DB 0D9H,12H,2BH,12H,7DH,11H,0D0H,10H,23H,10H
04EE    7D11D010
04F2    2310
04F4    780FCE0E  DB 78H,0FH,0CEH,0EH,26H,0EH,7EH,0DH,0D9H,0CH
04F8    260E7E0D
04FC    D90C
04FE    370C960B  DB 37H,0CH,96H,0BH,0F8H,0AH,5DH,0AH,0C4H,09H
0502    F80A5D0A
```

```
0506   C409
0508   2E099C08 DB 2EH,09H,9CH,08H,0DH,08H,82H,07H,0FAH,06H
050C   0D08R207
0510   FA05
0512   0A06F605 DB 0DAH,06H,0F6H,05H,78H,05H,04H,05H,91H,04H
0516   73050405
051A   9104
051C   23048303 DB 23H,04H,0BBH,03H,56H,03H,0F7H,02H,9DH,02H
0520   5503F702
0524   9D02
0526   4902FA01 DB 49H,02H,0FAH,01H,0B0H,01H,6CH,01H,2CH,01H
052A   B0016C01
052E   2C01
0530   F400C200 DB 0F4H,00H,0C2H,00H,94H,00H,06DH,00H,4CH,00H
0534   94006D00
0538   4C00
053A   30001800 DB 30H,00H,18H,00H,0CH,00H,03H,00H,00H,00H
053E   0C000300
0542   0000
                END
NO PROGRAM ERRORS
```


SYMBOL TABLE

```
* 01

A      0007     AMUA   4056     APPAR  0289     ARMAN  01AB
ASHIR  0394     B      0000     BASE   4065     BLADE  03AF
BOTHM  00A2     C      0001     CAMPA  02FD     CANAL  0256
CABIO  037E     CHINT  03CA     COALA  02C0  *  COSTA  0490
CHPPI  6003     D      0002     DATUM  4000     DECRE  0094
DELHI  0365     DERIV  0344     DIVIS  0395     DONE   0412
DOWER  00AC     DUSTL  039A     E      0003     ERASE  041C
FIFTH  4062     FINES  0148     FIRST  4059     FLAKE  0017
FORTH  4060     FRESH  0082     GANDT  01F2     GHOST  009B
GUDDI  021C     H      0004     HARAM  01A1     HOLDG  005C
IANGL  4058     IMPAN  02A2     INCR   008C     INTIC  4064
IONA   03FB     JANAK  0214     KARAM  01E5     KARZ   01DC
KEY    00C8     KISAN  0190     KORAR  0376     KUTAB  01AF
L      0005     LAMB   0021     LIMCA  02F4     LIME   010E
LIQUD  03FC     LOCK   00C5     LSUB   03F3     M      0006
MANDI  0200     MAXY   00D2     MINTO  03C4     MONA   028C
MSUB   0282     MULTI  0377     NAMAK  0197     NATH   016E
ORGIN  006F     PANAM  0242     PATIL  0233     PEPSI  0341
PHULN  0133     PORTC  6002     PORTI  6001     PORTV  6000
POWER  029C     PSW    0006     PURI   0219     RAJNI  0358
RANY   035E     RIVER  0257     RST75  003C  *  SALT   0286
SAMPL  00A1     SCROL  031E     SECND  405C     SHIFT  0338
SIGN   0383     SIPPU  03FA     SOANG  0243     SOAP   03AC
SOHAN  024A     SOLO   00D7     SP     0006     STONE  02AB
SUBZI  020F     SUGAR  02B8     SONOR  0139     TANJT  0410
THIRD  405E     TRCCI  037A     TRIP1  041E     TRIP2  0426
TRIP3  042E     TUNES  015C     VANGL  4057     VBASE  4066
VDERI  4067     VENKT  006B     [illegible]  0387     WATER  0386
ZCAL   00E2     ZONE2  0306     ZONE3  0327
```

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                     ;-------------------------------------------------------
                     ;    REAL TIME MICROPROCESSOR BASED PROGRAMME
                     ;    FOR QUADILATERAL CHRACTERISTIC DEVELOPED
                     ;    USING FUNDAMENTAL COMPONENT METHOD TAKING
                     ;    SAMPLES OVER ONE-HALF POWER CYCLE
                     ;-------------------------------------------------------
                     ; ASSIGNMENT MEMORY LOCATION FOR VARIABLES
4000                 DATUM EQU 4000H   ;FOR STORING OF SAMPLES
6000                 PORTV EQU 6000H   ;PORT 1 FOR VOLTAGE SAMPLE
6001                 PORTI EQU 6001H   ;PORT 2 FOR CURRENT SAMPLE
4020                 FIRST EQU 4020H
4022                 SECND EQU 4022H
4024                 THIRD EQU 4024H
4026                 INTIC EQU 4026H
0500                 COSTE EQU 0500H
0520                 SINTE EQU 0520H
0540                 MITHN EQU 0540H
4027                 RESIS EQU 4027H     ;STORING RESISTANCE
4028                 REACT EQU 4028H     ;STORING REACTANCE
4029                 VOLR   EQU 4029H ;  VD COMPONENT OF VOLTAGE
402A                 VOLQ   EQU 402AH  ;  VQ COMPONENT OF VOLTAGE
402B                 IOLR   EQU 402BH   ;ID COMPONENT OF CURRENT
402C                 IOLQ   EQU 402CH   ; IQ COMPONENT OF CURRENT
402D                 COUNT EQU 402DH
402E                 TIGER EQU 402EH
4030                 KOMAL EQU 4030H
4032                 JAKIN EQU 4032H     ;FAULTED SAMPLES
6002                 PORTC EQU 6002H     ;PORT C OF PPI
6003                 CWPPI EQU 6003H     ;CONTROL WORD OF PPI
0000                 ORG 0000H
0000    31FF42       LXI SP,42FFH
                     ;+++++++++++++++++++++++++++++++++++++++++++++++++
                     ;INTIALISATION OF INPUTPORTS/OUTPUTPORTS AND
                     ;COUNTERS, LOADING OF CONSTANTS
                     ;+++++++++++++++++++++++++++++++++++++++++++++++++
0003    3E93         MVI A,93H
0005    320360       STA CWPPI
0008    3E00         MVI A,00H
000A    320260       STA PORTC
000D    3E00         MVI A,00H
000F    323040       STA KOMAL
0012    210040       LXI H,DATUM
0015    0E0C         MVI C,0CH
0017    3A0260      FLAKE: LDA PORTC
001A    1F           RAR
001B    DA2100       JC LAMB
001E    C31700       JMP FLAKE
0021    3A0060      LAMB : LDA PORTV
0024    CDEF02       CALL DELHI
0027    77           MOV M,A
0028    23           INX H
0029    3A0160       LDA PORTI
002C    CDEF02       CALL DELHI
002F    77           MOV M,A
0030    0D           DCR C
0031    CA8200       JZ JRESH
0034    C31700       JMP FLAKE
0037    00           NOP
0038    00           NOP
0039    00           NOP
003A    00           NOP
003B    00           NOP
003C    F5          RST75 :  PUSH PSW
003D    E5           PUSH H
003E    D5           PUSH D
003F    3A2640       LDA INTIC
0042    FE00         CPI 0H
0044    CA5C00       JZ HOLDG
0047    57           MOV D,A
0048    3E0C         MVI A,0CH
004A    92           SUB D
004B    210040       LXI H,DATUM
004E    5F           MOV E,A
004F    1600         MVI D,0H
```

```
0051    19          DAD D
0052    3A0060      LDA PORTV
0055    CDEF02      CALL DELHI
0058    77          MOV M,A
0059    C36B00      JMP VENKT
005C    3E0C       HOLDG: MVI A,0CH
005E    322640      STA INTIC
0061    210040      LXI H,DATUM
0064    3A0060      LDA PORTV
0067    CDEF02      CALL DELHI
006A    77          MOV M,A
006B    D1         VENKI: POP D
006C    E1          POP H
006D    F1          POP PSW
006E    C9          RET
006F    3A2640     ORGIN: LDA INTIC
0072    4F          MOV C,A
0073    3E0C        MVI A,0CH
0075    91          SUB C
0076    210040      LXI H,DATUM
0079    5F          MOV E,A
007A    1600        MVI D,0H
007C    19          DAD D
007D    1E00        MVI E,0H
007F    C38900      JMP CHEMS
                   ;-----------------------------------------------------
                   ;COLLECTION OF SAMPLES OF VOLTAGE AND CURRENT AND
                   ;CYCLE BY CYCLE COMPARISON OF VOLTAGE SAMPLES AND
                   ;REPLACING THE PREVIOUS BY LATEST SAMPLES OF V$ C.
                   ;-----------------------------------------------------
0082    1E00       JRESH: MVI E,00H
0084    0E0C       FRESH: MVI C,0CH
0086    210040      LXI H,DATUM
0089    3A0260     CHEMS: LDA PORTC
008C    1F          RAR
008D    DA9300      JC CSOI
0090    C38900      JMP CHEMS
0093    CDB702     CSOI : CALL SAMP
0096    3E07        MVI A,07H
0098    BB          CMP E
0099    CAA700      JZ CALCU
009C    AF          XRA A
009D    79          MOV A,C
009E    FE00        CPI 00H
00A0    CA8400      JZ FRESH
00A3    23          INX H
00A4    C38900      JMP CHEMS
00A7    79         CALCU: MOV A,C
00A8    322640      STA INTIC
00AB    0606        MVI B,06H
00AD    B8          CMP B
00AE    DACE00      JC PENTR
00B1    90          SUB B
00B2    4F          MOV C,A
00B3    78          MOV A,B
00B4    91          SUB C
00B5    323040      STA KOMAL
00B8    3E0B        MVI A,0BH
00BA    91          SUB C
00BB    0C          INR C
00BC    113240      LXI D,JAKIN
00BF    CDF903      CALL BNZIR
00C2    3A3040      LDA KOMAL
00C5    4F          MOV C,A
00C6    3E00        MVI A,00H
00C8    CDF903      CALL BNZIR
00CB    C3DB00      JMP KRODI
00CE    80         PENTR: ADD B
00CF    47          MOV B,A
00D0    3E0B        MVI A,0BH
00D2    90          SUB B
00D3    0E07        MVI C,07H
00D5    113240      LXI D,JAKIN
00D8    CDF903      CALL BNZIR
```

```
                   ;-----------------------------------------
                   ;    CALCULATION OF VD
                   ;-----------------------------------------
00DB    213240     KRODI: LXI H,JAKIN
00DE    112D40      LXI D,COUNT
00E1    3E07        MVI A,07H
00E3    EB          XCHG
00E4    77          MOV M,A
00E5    D5          PUSH D    ;FIRST LOCATION WHERE FUNDAMENTAL COMPO STO
00E6    210000       LXI H,0000H
00E9    222040      SHLD FIRST
00EC    210005      LXI H,COSTE
00EF    CDFF02      CALL SUMMA
00F2    EB          XCHG
00F3    212940      LXI H,VOLR ; PLACE FOR STORING VD
00F6    73          MOV M,E
00F7    D1          POP D
                   ;-----------------------------------------
                   ;    CALCULATION OF VQ
                   ;-----------------------------------------
00F8    D5          PUSH D
00F9    212D40      LXI H,COUNT
00FC    3E07        MVI A,07H
00FE    77          MOV M,A
00FF    210000      LXI H,0000H
0102    222040      SHLD FIRST
0105    212005      LXI H,SINTE
0108    CDFF02      CALL SUMMA
010B    0650        MVI B,50H
010D    CD1504      CALL VISON
0110    AF          XRA A
0111    7A          MOV A,D
0112    17          RAL
0113    57          MOV D,A
0114    212A40       LXI H,VOLQ
0117    72          MOV M,D
0118    D1          POP D
                   ;-----------------------------------------
                   ;    CALCULATION OF ID
                   ;-----------------------------------------
0119    13          INX D
011A    D5          PUSH D
011B    212D40      LXI H,COUNT
011E    3E07        MVI A,07H
0120    77          MOV M,A
0121    210000      LXI H,0000H
0124    222040      SHLD FIRST
0127    210005      LXI H,COSTE
012A    CDFF02      CALL SUMMA
012D    EB          XCHG
012E    212B40      LXI H, IOLR
0131    73          MOV M,E
0132    D1          POP D
                   ;-----------------------------------------
                   ;    CALCULATION OF IQ
                   ;-----------------------------------------
0133    212D40      LXI H,COUNT
0136    3E07        MVI A,07H
0138    77          MOV M,A
0139    210000      LXI H,0000H
013C    222040      SHLD FIRST
013F    212005      LXI H,SINTE
0142    CDFF02      CALL SUMMA
0145    0650        MVI B,50H
0147    CD1504      CALL VISON
014A    AF          XRA A
014B    7A          MOV A,D
014C    17          RAL
014D    57          MOV D,A
014E    212C40      LXI H,IOLQ
0151    72           MOV M,D
                   ;
                   ;
                   ;
```

```
                    ;
                    ;
                    ;-----------------------------------------------
                    ;
                    ;     R=VD*ID+VQ*IQ/ ID**2 +IQ**2
                    ;
                    ;-----------------------------------------------
0152    212940            LXI H,VDLR
0155    46          MOV B,M
                    ;
0156    23          INX H
0157    23          INX H
0158    4E          MOV C,M
0159    2B          DCX H
015A    E5          PUSH H
015B    CD9E03      CALL MULTI    ; TO CALCULATE VD*ID
015E    222E40      SHLD TIGER
0161    E1          POP H
0162    46          MOV B,M
0163    23          INX H
0164    23          INX H
0165    4E          MOV C,M
0166    E5          PUSH H
0167    CD9E03      CALL MULTI   ; TO CALCULATE VQ*IQ
016A    EB          XCHG
016B    2A2E40      LHLD TIGER
016E    19          DAD D
016F    222E40      SHLD TIGER ;SUM OF VD*ID+VQ*IQ IS STORED FIRST&FIRST
0172    E1          POP H
0173    46          MOV B,M      ; CONTENTS OF IDLQ (IQ) MOVED TO REG B
0174    48          MOV C,B
0175    2B          DCX H
0176    E5          PUSH H
0177    CD9E03      CALL MULTI   ;TO CALCULATE (IQ**2)
017A    222240      SHLD SECND
017D    E1           POP H
017E    46          MOV B,M
017F    48          MOV C,B
0180    CD9E03      CALL MULTI   ; TO CALCULATE (ID**2)
0183    EB          XCHG
0184    2A2240       LHLD SECND
0187    19          DAD D
0188    222240      SHLD SECND    ;SUM OF (ID**2+IQ**2)IS STORED AT SECND
                    ;-----------------------------------------------
                    ;
                    ;     R=  TIGER / SECND
                    ;-----------------------------------------------
                    ;     LHLD SECND    NOT REQUIRED
018B    EB          XCHG
018C    2A2E40      LHLD TIGER
018F    29          DAD H
0190    29          DAD H
0191    29          DAD H
0192    222040      SHLD FIRST
0195    2A2E40      LHLD TIGER
0198    29          DAD H
0199    4D          MOV C,L
019A    44          MOV B,H
019B    2A2040      LHLD FIRST
019E    09          DAD B
019F    4D          MOV C,L
01A0    44          MOV B,H
01A1    CD8004      CALL LISON
01A4    212740      LXI H,RESIS
01A7    71          MOV M,C
                    ; ----------------------------------------------
                    ;     X=VQ*ID - VD*IQ/ID**2+IQ**2
                    ;-----------------------------------------------
01A8    212A40      LXI H,VOLQ
01AB    46          MOV B,M
01AC    23          INX H
01AD    4E          MOV C,M
01AE    23          INX H
01AF    E5          PUSH H
```

```
0180   CD9E03   CALL MULTI   ; TO CALCULATE VQ*ID
0183   222440   SHLD THIRD
0186   E1       POP H
0187   46        MOV B,M
0188   2B       DCX H
0189   2B       DCX H
018A   2B       DCX H
018B   4E       MOV C,M
018C   CD9E03   CALL MULTI   ; TO CALCULATE VD*IQ
018F   CD7704   CALL TWOCM
01C2   EB       XCHG
01C3   2A2440   LHLD THIRD
01C6   19       DAD D
01C7   222440   SHLD THIRD
                ;-------------------------------------------------
                ;TO CALCULATE X =THIRD/SECND
                ;-------------------------------------------------
                ; LHLD THIRD NOT REQUIRED
01CA   29       DAD H
01CB   29       DAD H
01CC   29       DAD H
01CD   222040   SHLD FIRST
01D0   2A2440   LHLD THIRD
01D3   29       DAD H
01D4   4D       MOV C,L
01D5   44       MOV B,H
01D6   2A2040   LHLD FIRST
01D9   09       DAD B
01DA   4D       MOV C,L
01DB   44       MOV B,H
01DC   2A2240   LHLD SECND
01DF   EB       XCHG
01E0   CD8004   CALL LISON
01E3   212840   LXI H,REACT
01E6   71       MOV M,C
                ;-------------------------------------------------
                ;RELAY LOGIC FOR QUADRILATERAL CHRACTERISTIC
                ;TO CHECK WHETHER R>0 OR NOT
                ;O CHECK WHETHER X > 0 OR NOT
                ;TO CHECK WHETHER R < R3 OR NOT
                ; TO CHECK WHETHER R < R2
                ; TO CHECK WHETHER R > R1 OR NOT
                ; TO CHECK WHETHER K4 > K2  K4=X/R-R2, K2=X1/R3-R2
                ; TO CHECK WHETHER K3 <K1 K3=X/R K1=X1/R1
                ; TO CHECK FOR ZONE1  ZONE2   ZONE3
                ;-------------------------------------------------
01E7   AF       XRA A
01E8   212740   LXI H,RESIS
01EB   46       MOV B,M
01EC   23       INX H
01ED   4E       MOV C,M    ;REG B=RESISTANCE, REG C=REACTANCE
                ; TO CHECK WHETHER R > 0 OR NOT
01EE   78       MOV A,B
01EF   B7       ORA A
01F0   FA6F00   JM ORGIN
                ; TO CHECK WHETHER X> 0 OR NOT
01F3   79       MOV A,C
01F4   B7       ORA A
01F5   FA6F00   JM ORGIN
                ; TO CHECK WHETHER X< X1
01F8   161E     MVI D,1EH
01FA   BA       CMP D
01FB   D23B02   JNC ZONE2
                ;TO CHECK WHETHER R < R3 OR NOT
01FE   1611     MVI D,11H
0200   78       MOV A,B
0201   BA       CMP D
0202   D23B02   JNC ZONE2
                ; TO CHECK WHETHER R <R2
0205   160E     MVI D,0EH
0207   BA       CMP D
0208   D21402   JNC ARMAN
                ; TO CHECK WHETHER R >R1
020B   1603     MVI D,03H
```

```
0020D  BA        CMP D
020E   DA2702    JC APPU
0211   C3C504    JMP TRIP1
                 ; TO CHECK WHETHER K4 >K2 AND CALCULATION OF K4
0214   AF        ARMAN: XRA A
0215   160E      MVI D,0EH
0217   78        MOV A,B
0218   92        SUB D
0219   47        MOV B,A
021A   CD5304    CALL DIVIS
021D   7A        MOV A,D
021E   160A      MVI D,0AH
0220   BA        CMP D
0221   DA6F00    JC ORGIN
0224   C3C504    JMP TRIP1
                 ; TO CHECK WHETHER K3 < K1
0227   AF        APPU : XRA A
0228   CD5304    CALL DIVIS
022B   7A        MOV A,D
022C   160A      MVI D,0AH
022E   BA        CMP D
022F   D23502    JNC LRESH
0232   C3C504    JMP TRIP1
0235   CAC504    LRESH: JZ TRIP1
0238   C38400    JMP FRESH
                 ;+++++++++++++++++++++++++++++++++++++++++++++
                 ; TO CHECK FOR ZONE2 OPERATION
                 ;+++++++++++++++++++++++++++++++++++++++++++++
                 ;TO CHECK WHETHER X < X1
023B   163C      ZONE2: MVI D,3CH
023D   79        MOV A,C
023E   BA        CMP D
023F   D27902    JNC ZONE3
                 ;TO CHECK WHETHER R<R3 OR NOT
0242   1614      MVI D,14H
0244   78        MOV A,B
0245   BA        CMP D
0246   D27902    JNC ZONE3
                 ;TO CHECK WHETHER R<R2 OR NOT
0249   160E      MVI D,0EH
024B   BA        CMP D
024C   D25802    JNC ZSMPP
                 ; TO CHECK WHETHER R>R1
024F   1606      MVI D,06H
0251   BA        CMP D
0252   DA6B02    JC QSTRI
0255   C3CD04    JMP TRIP2
                 ;TO CHECK WHETHER K4>K2 AND CALCULATION OF K4
0258   AF        ZSMPP: XRA A
0259   160E      MVI D,0EH
025B   78        MOV A,B
025C   92        SUB D
025D   47        MOV B,A
025E   CD5304    CALL DIVIS
0261   7A        MOV A,D
0262   160A      MVI D,0AH
0264   BA        CMP D
0265   DA6F00    JC ORGIN
0268   C3CD04    JMP TRIP2
                 ;TO CHECK WHETHER K3<K1
026B   AF        QSTRI: XRA A
026C   CD5304    CALL DIVIS
026F   7A        MOV A,D
0270   160A      MVI D,0AH
0272   BA        CMP D
0273   D26F00    JNC ORGIN
0276   C3CD04    JMP TRIP2
                 ;+++++++++++++++++++++++++++++++++++++++++++++
                 ;TO CHECK FOR ZONE3 OPERATION
                 ;+++++++++++++++++++++++++++++++++++++++++++++

                 ;TO CHECK WHETHER X < X1
0279   165A      ZONE3: MVI D,5AH
027B   79        MOV A,C
```

```
027C   BA       CMP D
027D   D26F00   JNC ORGIN
                ;TO CHECK WHETHER R<R3 OR NOT
0280   1617     MVI D,17H
0282   78       MOV A,B
0283   BA       CMP D
0284   D26F00   JNC ORGIN
                ;TO CHECK WHETHER R<R2 OR NOT
0287   160E     MVI D,0EH
0289   BA       CMP D
028A   D29602   JNC PSMMM
                ; TO CHECK WHETHER R>R1
028D   1609     MVI D,09H
028F   BA       CMP D
0290   DAA902   JC MALOP
0293   C3D504   JMP TRIP3
                ;TO CHECK WHETHER K4>K2 AND CALCULATION OF K4
0296   AF       PSMMM: XRA A
0297   160E     MVI D,0EH
0299   78       MOV A,B
029A   92       SUB D
029B   47       MOV B,A
029C   CD5304   CALL DIVIS
029F   7A       MOV A,D
02A0   160A     MVI D,0AH
02A2   BA       CMP D
02A3   DA6F00   JC ORGIN
02A6   C3D504   JMP TRIP3
                ;TO CHECK WHETHER K3<K1
02A9   AF       MALOP: XRA A
02AA   CD5304   CALL DIVIS
02AD   7A       MOV A,D
02AE   160A     MVI D,0AH
02B0   BA       CMP D
02B1   D26F00   JNC ORGIN
02B4   C3D504   JMP TRIP3
                ;-----------------------------------------------------------
                ;               SUBROUTINES
                ;-----------------------------------------------------------
02B7   46       SAMP : MOV B,M
02B8   3AD060   LDA PORTV
02BB   CDEF02   CALL DELHI
02BE   77       MOV M,A
02BF   23       INX H
02C0   3AD160   LDA PORTI
02C3   CDEF02   CALL DELHI
02C6   77       MOV M,A
02C7   2B       DCX H
                ;TO COMPARE THE VOLTAGE SAMPLES
02C8   78       MOV A,B
02C9   56       MOV D,M
02CA   BA       CMP D
02CB   DAD102   JC LOCK
02CE   C3D302   JMP KEY
02D1   7A       LOCK : MOV A,D
02D2   50       MOV D,B
02D3   92       KEY  : SUB D
02D4   1605     MVI D,05H
02D6   BA       CMP D
02D7   DADD02   JC MAXY
02DA   C3EB02   JMP SOLD
02DD   AF       MAXY : XRA A
02DE   23       INX H
02DF   3E00     MVI A,00H
02E1   BB       CMP E
02E2   CAE602   JZ GHOST
02E5   1D       DCR E
02E6   AF       GHOST: XRA A
02E7   0D       DCR C
02E8   C3EE02   JMP JULLD
02EB   1C       SOLO : INR E
02EC   23       INX H
02ED   0D       DCR C
02EE   C9       JULLD:RET
```

```
                        ;++++++++++++++++++++++++++++++++++++++++++++++++
                        ;TO CONVRT THE OFFSET BINARY NUMBER
                        ;++++++++++++++++++++++++++++++++++++++++++++++++
02EF    37              DELHI: STC
02F0    3F               CMC
02F1    17               RAL
02F2    DAFB02           JC RAJNI
02F5    1F               RAR
02F6    F680             ORI 10000000B
02F8    C3FE02           JMP KORAR
02FB    1F              RAJNI: RAR
02FC    E67F             ANI 01111111B
02FE    C9              KORAR: RET
                        ;------------------------------------------------
                        ;  TO CALCULATE THE SUM OVER DATA WINDOW
                        ;------------------------------------------------
02FF    AF              SUMMA: XRA A
0300    46               MOV B,M
0301    23               INX H
0302    EB               XCHG
0303    4E               MOV C,M
0304    23               INX H
0305    23               INX H
0306    EB               XCHG
0307    E5               PUSH H
0308    D5               PUSH D
0309    78               MOV A,B
030A    B7               ORA A
030B    F21003           JP MONDI
030E    2F               CMA
030F    3C               INR A
0310    1603            MONDI: MVI D,03H
0312    BA               CMP D
0313    DA1D03           JC SURII
0316    AF               XRA A
0317    CD9E03           CALL MULTI
031A    C32003           JMP LURID
031D    CD5A03          SURII: CALL COSMJ
0320    EB              LURID: XCHG
0321    2A2040           LHLD FIRST
0324    19               DAD D
0325    222040           SHLD FIRST
0328    212D40           LXI H,COUNT
032B    7E               MOV A,M
032C    3D               DCR A
032D    C23303           JNZ PATIL
0330    C33903           JMP KIRTI
0333    77              PATIL: MOV M,A
0334    D1               POP D
0335    E1               POP H
0336    C3FF02           JMP SUMMA
0339    D1              KIRTI: POP D
033A    E1               POP H
033B    2A2040           LHLD FIRST
033E    7C               MOV A,H
033F    B7               ORA A
0340    FA4C03           JM BINDU
0343    7C               MOV A,H
0344    1F               RAR
0345    67               MOV H,A
0346    7D               MOV A,L
0347    1F               RAR
0348    6F               MOV L,A
0349    C35903           JMP RDBUR
034C    CD7704          BINDU: CALL TWOCM
034F    AF               XRA A
0350    7C               MOV A,H
0351    1F               RAR
0352    67               MOV H,A
0353    7D               MOV A,L
0354    1F               RAR
0355    6F               MOV L,A
0356    CD7704           CALL TWOCM
0359    C9              RDBUR:  RET
```

```
                      ;
                      ;
                      ;
                      ;
                      ;
                      ;+++++++++++++++++++++++++++++++++++++++++++++++
                      ;TO CALCULATE THE PRODUCT OF COSINE TERMS
                      ;+++++++++++++++++++++++++++++++++++++++++++++++
035A    C5            COSMU: PUSH B    ;REG B =CONSTANT REG C =SAMPLE VALUE
035B    78             MOV A,B
035C    B7             ORA A
035D    F26303         JP DVOS
0360    2F             CMA
0361    3C             INR A
0362    47             MOV B,A
0363    79            DVOS : MOV A,C
0364    B7             ORA A
0365    F26B03         JP VALM
0368    2F             CMA
0369    3C             INR A
036A    4F             MOV C,A
036B    78            VALM : MOV A,B
036C    FE00           CPI 00H
036E    CA9903         JZ SINGM
0371    79             MOV A,C
0372    FE00           CPI 00H
0374    CA9903         JZ SINGM
0377    210000         LXI H,0000H
037A    1600           MVI D,00H
037C    59             MOV E,C
037D    19            ARADN: DAD D
037E    05             DCR B
037F    CA8503         JZ MANJI
0382    C37D03         JMP ARADN
0385    C1            MANJI: POP B
0386    AF             XRA A
0387    78             MOV A,B
0388    A9             XRA C
0389    FA8F03         JM GUDWR
038C    C39D03         JMP NANKA
038F    7D            GUDWR: MOV A,L
0390    2F             CMA
0391    6F             MOV L,A
0392    7C             MOV A,H
0393    2F             CMA
0394    67             MOV H,A
0395    23             INX H
0396    C39D03         JMP NANKA
0399    C1            SINGM: POP B
039A    210000         LXI H,0000H
039D    C9            NANKA: RET
                      ;-----------------------------------------------
                      ; MULTIPLICATION  REG B=CONSTANT REG C=SAMPLE
                      ;-----------------------------------------------
039E    C5            MULTI: PUSH B
039F    78             MOV A,B
03A0    E680           ANI 10000000B
03A2    FE00           CPI 00H
03A4    CAAB03         JZ  GARG
03A7    78             MOV A,B
03A8    2F             CMA
03A9    3C             INR A
03AA    47             MOV B,A
03AB    79            GARG: MOV A,C
03AC    E680           ANI 10000000B
03AE    FE00           CPI 00H
03B0    CAB703         JZ ABHA
03B3    79             MOV A,C
03B4    2F             CMA
03B5    3C             INR A
03B6    4F             MOV C,A
03B7    78            ABHA : MOV A,B
03B8    FE00           CPI 00H
03BA    CAF403         JZ RITA
```

```
03BD    79        MOV A,C
03BE    FE00      CPI 00H
03C0    CAF403    JZ RITA
03C3    78        MOV A,B;REGA=MULTIPLIER REG C=MULTIPLICANT RES IN H-.
03C4    210000    LXI H,00H
03C7    1608      MVI D,08H
03C9    44        MOV B,H
03CA    0F       CASIO: RRC
03CB    D2CF03    JNC SIGN
03CE    09        DAD B
03CF    15       SIGN : DCR D
03D0    CAE003    JZ ASHTR
03D3    5F        MOV E,A
03D4    79        MOV A,C
03D5    37        STC
03D6    3F        CMC
03D7    17        RAL
03D8    4F        MOV C,A
03D9    78        MOV A,B
03DA    17        RAL
03DB    47        MOV B,A
03DC    7B        MOV A,E
03DD    C3CA03    JMP CASIO
03E0    C1       ASHTR: POP B
03E1    AF        XRA A
03E2    78        MOV A,B
03E3    A9        XRA C
03E4    FAEA03               JM KUWAT
03E7    C3F803    JMP ARABN
03EA    7D       KUWAT: MOV A,L
03EB    2F        CMA
03EC    6F        MOV L,A
03ED    7C        MOV A,H
03EE    2F        CMA
03EF    67        MOV H,A
03F0    23        INX H
03F1    C3F803    JMP ARABN
03F4    C1       RITA : POP B
03F5    210000    LXI H,0000H
03F8    C9       ARABN: RET
                 ;++++++++++++++++++++++++++++++++++++++++++++++
                 ;TO DERIVE SINGLE PHASE RELAYING QUATITIES
                 ;++++++++++++++++++++++++++++++++++++++++++++++=.
03F9    214005   BNZIR :LXI H,MITHN
03FC    85        ADD L
03FD    6F        MOV L,A
03FE    7E        MOV A,M
03FF    210040    LXI H,DATUM
0402    85        ADD L
0403    6F        MOV L,A
0404    7E       ROMA: MOV A,M
0405    EB        XCHG
0406    77        MOV M,A
0407    23        INX H
0408    EB        XCHG
0409    23        INX H
040A    7E        MOV A,M
040B    EB        XCHG
040C    77        MOV M,A
040D    23        INX H
040E    EB        XCHG
040F    23        INX H
0410    0D        DCR C
0411    C20404    JNZ ROMA
0414    C9        RET    ;
                 ;++++++++++++++++++++++++++++++++++++
                 ;      16BIT DIVISON SUBROUTINE
                 ;++++++++++++++++++++++++++++++++++++++++++++++++
0415    E5       VISON: PUSH H
0416    7C        MOV A,H
0417    E680      ANI 10000000B
0419    FE00      CPI 00H
041B    CA2504    JZ RINKU
041E    7C        MOV A,H
```

```
041F    2F        CMA
0420    67        MOV H,A
0421    7D        MOV A,L
0422    2F        CMA
0423    6F        MOV L,A
0424    23        INX H
0425    1600      RINKU: MVI D,00H
0427    1E00      MVI E,00H
0429    7B        CHINT: MOV A,E
042A    FE08      CPI 08H
042C    CA3E04    JZ MINTO
042F    29        DAD H
0430    1C        INR E
0431    7A        MOV A,D
0432    07        RLC
0433    57        MOV D,A
0434    7C        MOV A,H
0435    90        SUB B
0436    DA3B04    JC BAWA
0439    14        INR D
043A    67        MOV H,A
043B    C32904    BAWA :  JMP CHINT
043E    7C        MINTO: MOV A,H
043F    07        RLC
0440    B8        CMP B
0441    DA4504    JC BANTI
0444    14        INR D
0445    E1        BANTI: POP H
0446    7C        MOV A,H
0447    E680      ANI 10000000B
0449    FE00      CPI 00H
044B    CA5204    JZ NEEL
044E    7A        MOV A,D
044F    2F        CMA
0450    57        MOV D,A
0451    14        INR D
0452    C9        NEEL : RET
                  ;-----------------------------------------------
                  ;    DIVISON
                  ;-----------------------------------------------
0453    AF        DIVIS: XRA A
0454    78        MOV A,B
0455    69        MOV L,C
0456    2600      MVI H,00H
0458    54        MOV D,H
0459    5C        MOV E,H
045A    7B        DUSTL: MOV A,E
045B    FE08      CPI 08H
045D    CA6F04    JZ BLADE
0460    29        DAD H
0461    1C        INR E
0462    7A        MOV A,D
0463    07        RLC
0464    57        MOV D,A
0465    7C        MOV A,H
0466    90        SUB B
0467    DA6C04    JC SOAP
046A    14        INR D
046B    67        MOV H,A
046C    C35A04    SOAP : JMP DUSTL
046F    7C        BLADE : MOV A,H
0470    07        RLC
0471    B8        CMP B
0472    DA7604    JC WATER
0475    14        INR D
0476    C9        WATER: RET
                  ;------------------------------------------
                  ;    TWOCM
                  ;------------------------------------------
0477    AF        TWOCM: XRA A
0478    7D        MOV A,L
0479    2F        CMA
047A    6F        MOV L,A
047B    7C        MOV A,H
```

```
047C    2F        CMA
047D    67        MOV H,A
047E    23        INX H
047F    C9        RET
                  ;
                  ;
                  ;
                  ;
                  ;=========================================================
                  ;16 BITS DIVISON SUBROUTINE REG B-C PAIR INTIALLY CON
                  ;REG PAIR  D-E CONTAINS DIVISOR AND IN THE END REG B-
                  ;QUOTIENT, REG D-E CONTAINS REMAINDER
                  ;=========================================================
0480    210000    LISON: LXI H,0000H
0483    D5         PUSH D
0484    7A         MOV A,D
0485    2F         CMA
0486    57         MOV D,A
0487    7B         MOV A,E
0488    2F         CMA
0489    5F         MOV E,A
048A    13         INX D
048B    3E11       MVI A,17D
048D    E5        LINTO: PUSH H
048E    19         DAD D
048F    D29304     JNC RHINT
0492    E3         XTHL
0493    E1        RHINT: POP H
0494    F5         PUSH PSW
0495    79         MOV A,C
0496    17         RAL
0497    4F         MOV C,A
0498    78         MOV A,B
0499    17         RAL
049A    47         MOV B,A
049B    7D         MOV A,L
049C    17         RAL
049D    6F         MOV L,A
049E    7C         MOV A,H
049F    17         RAL
04A0    67         MOV H,A
04A1    F1         POP PSW
04A2    3D         DCR A
04A3    C28D04     JNZ LINTO
                  ;SHIFT REMAINDER RIGHT & RETURN IN H-L
04A6    B7         ORA A
04A7    7C         MOV A,H
04A8    1F         RAR
04A9    67         MOV H,A
04AA    7D         MOV A,L
04AB    1F         RAR
04AC    6F         MOV L,A
04AD    29         DAD H
04AE    D1         POP D
04AF    7D         MOV A,L
04B0    BB         CMP E
04B1    DABC04     JC MSUB
04B4    7C         MOV A,H
04B5    BA         CMP D
04B6    DAC404     JC MONA
04B9    C3C304     JMP DIPPU
04BC    AF        MSUB : XRA A
04BD    7C         MOV A,H
04BE    3D         DCR A
04BF    BA         CMP D
04C0    DAC404     JC MONA
04C3    03        DIPPU: INX B
04C4    C9        MONA : RET ; REG B-C=QUOTIENT
                  ;---------------------------------------------------------
                  ;                     TRIP
                  ;---------------------------------------------------------
04C5    3E80      TRIP1 :MVI A,80H
04C7    320260     STA PORTC
04CA    C3C504     JMP TRIP1
```

```
04CD    3E20        TRIP2: MVI A,20H
04CF    320260       STA PORTC
04D2    C3CD04       JMP TRIP2
04D5    3E40        TRIP3: MVI A,40H
04D7    320260       STA PORTC
04DA    C3D504       JMP TRIP3
04DD    76           HLT
0520                 ORG SINTE
0520    00232300     DB 00H,23H,23H,00H,-23H,-23H
0524    DDDD00
0500                 ORG COSTE
0500    FFFF0102     DB -1H,-1H,1H,2H,1H,-1H,-1H
0504    01FFFF
0540                 ORG MITHN
0540    00020406     DB 00H,02H,04H,06H,08H,0AH,0CH,0EH,10H,12H,14H,16H
0544    080A0C0E
0548    10121416
                     END
NO PROGRAM ERRORS
```


SYMBOL TABLE

* 01

A	0007	ABHA	03B7	APPU	0227	ARABN	03F8
ARADN	037D	ARMAN	0214	ASHTR	03E0	B	0000
BANTI	0445	BAWA	043B	BINDU	034C	BLADE	046F
BNZIR	03F9	C	0001	CALCU	00A7	CASIO	03CA
CHEMS	0089	CHINT	0429	COSMU	035A	COSTE	0500
COUNT	402D	CSOI	0093	CWPPI	6003	D	0002
DATUM	4000	DELHI	02EF	DIPPU	04CB	DIVIS	0453
DUSTL	045A	DVDS	0363	E	0003	FIRST	4020
FLAKE	0017	FRESH	0084	GARG	03AB	GHOST	02E6
GUDWR	038F	H	0004	HOLOG	005C	INTIC	4026
IOLQ	402C	IOLR	402B	JAKIN	4032	JRESH	0082
JULLD	02EE	KEY	02D3	KIRTI	0339	KOMAL	4030
KORAR	02FE	KRODI	00DB	KUWAT	03EA	L	0005
LAMB	0021	LINTO	048D	LISON	0480	LOCK	02D1
LRESH	0235	LURID	0320	M	0006	MALOP	02A9
MANJI	0385	MAXY	02DD	MINTO	043E	MITHN	0540
MONA	04C4	MONDI	0310	MSUB	04BC	MULTI	039E
NANKA	039D	NEEL	0452	ORGIN	006F	PATIL	0333
PENTR	00CE	PORTC	6002	PORTI	6001	PORTV	6000
PSMMM	0296	PSW	0006	QSTRI	026B	RAJNI	02FB
ROBUR	0359	REACT	4028	RESIS	4027	RHINT	0493
RINKU	0425	RITA	03F4	ROMA	0404	RST75	003C *
SAMP	02B7	SECND	4022	SIGN	03CF	SINGM	0399
SINTE	0520	SOAP	046C	SOLO	02EB	SP	0006
SUMMA	02FF	SURII	031D	THIRD	4024	TIGER	402E
TRIP1	04C5	TRIP2	04CD	TRIP3	04D5	TWOCM	0477
VALM	036B	VENKT	006B	VISON	0415	VOLQ	402A
VOLR	4029	WATER	0476	ZONE2	023B	ZONE3	0279
ZSMPP	0258						